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Addendum to: 'Environmental Assessment Source Test and Evaluation Report Chapman Low-Btu Gasification'

Radian Corp.
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Prepared for

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16. ABSTRACT The report contains detailed organic analysis data on six streams, trace element and organic data on the solid waste leachates, and trace element data on the feed coal, all of which were not included in the original report, EPA-600/7-78-202. Samples from six streams were analyzed to provide a detailed organic characterization of emissions and potential fugitive emissions from an operating Chapman low-Btu gasifier using Virginia bituminous coal. The streams were: coal feeder vent discharge, separator vent discharge, separator liquor, separator tar, gasifier ash, and cyclone dust. All streams except the ash and dust contained organic compound concentrations of concern to health when evaluated using SAM/IA methodology. Phenols in the separator vent discharge and liquor and fused polycyclics in the coal feeder vent discharge and the separator tar were of greatest concern. When compared to screening data, potential effects were lower, but relative ranking of streams was essentially unchanged. The ash and dust were subjected to leachate extraction tests using the RCRA method and deionized water. No organics were found in the leachates. Concentrations of trace elements in the RCRA and deionized water leachates were different, but were found to have low potential for causing adverse health or ecological effects.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS		b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group	
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Assessments	Leaching	Stationary Sources	14B	07D/07A
Coal Gasification	Dust	Environmental Assessment	13H	11G
Tests	Aerosols			
Evaluation	Tars	Chapman Process	14G	07C
Organic Compounds	Phenols	Trace Elements	07C	

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ABSTRACT

This report acts as an addendum to "Source Test and Evaluation Report--Chapman Low-Btu Gasification" published by the Environmental Protection Agency in 1978. It contains detailed organic analysis data on six streams, trace element and organic data on the solid waste leachates and trace element data on the feed coal. These data were not included in the original report.

A total of six samples were analyzed by gas chromatography/mass spectrometry to provide a detailed organic characterization of emissions and potential fugitive emissions from an operating Chapman Low-Btu gasification facility using Virginia bituminous coal. The streams analyzed were: coal feeder vent discharge, separator vent discharge, separator liquor, separator tar, gasifier ash, and cyclone dust. The extractable organics in four of the 6 samples were fractionated using an acid-base-neutral fractionation scheme prior to analysis to simplify compound identification.

All streams analyzed except the ash and dust contained concentrations of organic compounds at levels of concern to health when evaluated by Source Assessment Model/1A (SAM/1A) methodology. Phenols in the separator vent discharge and liquor and fused polycyclics in the coal feeder vent discharge and the separator tar were identified as the compounds of greatest concern. When compared to screening data, potential effects are lower but relative ranking of streams is essentially unchanged.

In addition, trace element analysis was performed on the feed coal and trace element and organic loading analyses on Resource Conservation and Recovery Act (RCRA) and deionized water leachates of the gasifier ash and cyclone dust. The SAM/1A results indicate low potential health and ecological effects for samples from inorganic compounds. The organic analyses indicated no organic loading, and therefore, no contribution by organics to the SAM/1A results.

The concentration of all elements with RCRA specified limits were significantly below those limits. There were qualitative and quantitative differences between the RCRA and deionized water leachates.

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SECTION 1

INTRODUCTION

Radian Corporation of Austin, Texas, is performing a comprehensive environmental assessment of low- and medium-Btu gasification technology under a contract with the Environmental Protection Agency (EPA). A major portion of this assessment involves Source Test and Evaluation (STE) programs at operating low-Btu gasification facilities.

In 1978, Radian Corporation, in conjunction with the EPA, conducted an STE program at a commercial Chapman low-Btu gasification facility. The objectives of this program were, in part, to perform chemical and bioassay screening tests on the gasifier waste streams and potential fugitive emissions (process streams). These data were reported in the Source Test and Evaluation Report (STER) resulting from the Chapman STE program (Ref. 1).

The STE program did not include detailed organic characterization of any process or waste streams. It also did not include trace element analysis of the feed coal or trace element and organic loading analyses of the solid waste leachates. These analyses have now been performed on samples taken during the STE sampling campaign.

The purpose of this addendum to the Chapman STER is:

- To report the results of the detailed organic analyses of the gasifier waste streams and potential fugitive emissions (process streams),
- to report the results of additional testing of the feed coal and the leachates from the solid waste streams, and
- to provide conclusions and recommendations based on these additional data.

SECTION 2

CONCLUSIONS AND RECOMMENDATIONS

This section summarizes the results of the detailed organic analysis of the waste streams and potential fugitive emissions (process streams) from the Chapman facility and compares the detailed organic data to the Source Assessment Model/1A (SAM/1A) analysis (Ref. 2) of the chemical screening data. Summaries of the trace element analysis of the feed coal and the trace element and organic loading analyses of the solid waste leachates are presented. Finally, additional data needs and methodology recommendations are discussed.

2.1 SUMMARY OF THE RESULTS OF THE DETAILED ORGANIC ANALYSES AND THEIR COMPARISON TO THE SAM/1A ANALYSIS OF THE CHEMICAL SCREENING DATA

The Source Analysis Model/1A is used to identify and prioritize waste streams and potential fugitive emissions (process streams) that have potential for health and/or ecological effects. Specific compounds are assigned discharge multimedia environmental goal (DMEG) values (Ref. 3,4,5 and Appendix Table A-1). A DMEG value is a concentration of a substance estimated not to cause adverse effects in a health or ecological receptor. Discharge concentration (dc) by the DMEG. The total of the individual DS values charge concentration (dc) by the DMEG. The total of the individual DS values for the stream is expressed as the total discharge severity (TDS). When the discharge rate (mr) of the stream is multiplied by the DS value for a component the result is expressed as the Weighted Discharge Severity (WDS). The sum of the WDS values for a stream is expressed as the total weighted discharge severity (TWDS). The TDS values and TWDS values are used to rank streams in terms of potential effect and indicate the relative need for detailed analysis. In the original Chapman STER (Ref. 1) potential degree of hazard (PDOH) and potential toxic unit discharge rate (PTUDR) were used in place of and are synonymous with DS and WDS respectively. A glossary of environmental impact analyses terminology is given in Appendix B.

The waste streams and potential fugitive emissions subjected to detailed organic analysis and their total discharge severities (TDS) and total weighted discharge severities (TWDS) for extractable organics (Ref. 3,4,5 and Appendix Table A-1) are given in Table 2-1. All streams analyzed except the gasifier ash and the cylone dust contain concentrations of organic compounds yielding TDS health values greater than 1. In addition, the weighted discharge severity for the ash indicates potential ecological effects. However, it should be noted that these potential ecological effects are due primarily to phthalates. Phthalates are common artifacts in trace level organic analysis. The TWDS ecology value for the ash is reduced to 0.2 g/sec from 7 g/sec if the concentrations of the phthalates are excluded from the calculations. The cyclone

TABLE 2-1. DETAILED ORGANIC ANALYSIS: RESULTS OF THE SAM/1A ANALYSIS FOR ALL ORGANIC COMPOUNDS WITH ASSIGNED DMEG VALUES DETECTED BY GC/MS

	TDS (Organics)		TWDS (Organics)		
	Health	Ecology	Health	Ecology	Principle Compounds
Gaseous Waste Streams					
Coal Feeder Vent Discharge	4E4[1]	-	2E3 (m^3/sec)		Benzo(a)pyrene
Separator Vent Discharge	2E2	-	1E2 (m^3/sec)		Phenols
Solid Waste Streams					
Cyclone Dust	6E-6	1E-1	1E-5 (g/sec)	2E-1 (g/sec)	Phthalates
Gasifier Ash	2E-4	4E0	4E-3 (g/sec)	7E1 (g/sec)	Phthalates
Potential Fugitive Emissions					
Separator Liquor	1E2	1E3			Phenols
Separator Tar	3E6	-			Benzo(a)pyrene, Phenols

[1] aEb = a x 10^b

TDS: Total Discharge Severity
TWDS: Total Weighted Discharge Severity

dust has WDS values for organic compounds of less than 1 g/sec for both health and ecology.

Of the potential fugitive emissions, the extractable organics in the separator tar have the highest potential for health effects based on DMEG values for a liquid. Although the tar contains at least 15 compounds with a discharge severity (DS) >1, the primary compound contributing to the TDS is benzo(a)pyrene [B(a)P]. The analytical technique employed does not distinguish B(a)P from a group of up to six isomers of the same molecular weight (252). However, if it is assumed that only 15% of the mass attributed to B(a)P is actually contributed by B(a)P, the TDS for the stream still remains over 5E5 (5×10^5).

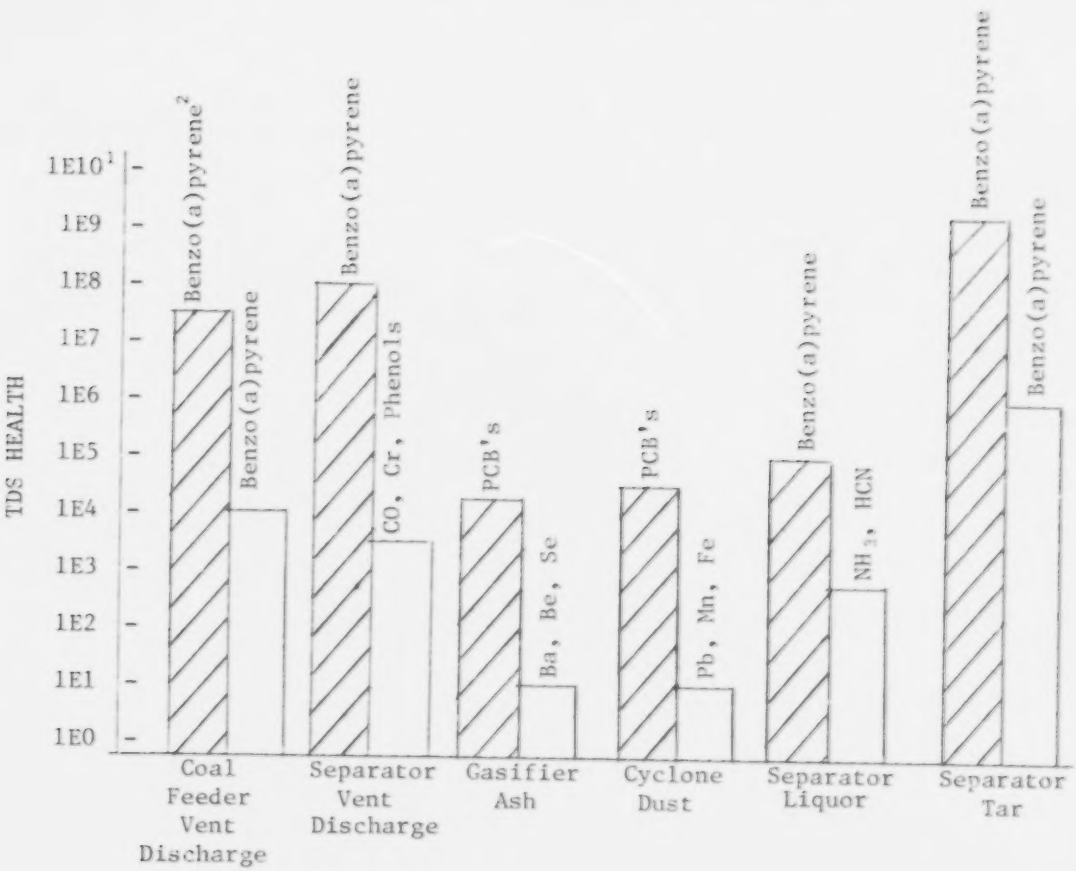
The extractable organics in the separator liquor have potential effects for both health and ecology, with organic TDS values of 1E2 and 1E3 respectively. For both health and ecology, phenols comprise the major group of compounds of concern with phthalates making a minor contribution to the potential ecological effects.

Recently a change in the DMEG values for phenol in water published in "Multimedia Environmental Goals for Environmental Assessment: Volume IV," (Ref. 2) from 5.0 to 1.7E4 µg/L for health and from 5.0E2 to 3.0E3 µg/L for ecology has been suggested by Research Triangle Institute based on 1979 proposed water quality criteria for phenols (Ref. 6). The proposed values for phenol are applied to all phenolic compounds which had previously been assigned DMEG health and ecology values of 5.0 µg/L and 5.0E2 µg/L respectively.

The extractable organics from the XAD-2 resin, organic module rinses, probe rinse and condensate from both the gaseous waste streams, the coal feeder vent discharge and the separator vent discharge, have organic TDS health values of 4E4 and 2E2 and TWDS health values of 2E3 and 1E2 m^3/sec respectively. The major compounds of concern are B(a)P for the coal feeder vent discharge and phenols for the separator vent discharge.

A comparison of the TDS and TWDS values from the chemical screening data and the detailed analytical data for the total streams (organics and inorganics) is given in Figures 2-1 through 2-3. The values for the chemical screening data are calculated from data given in the Chapman STER (Ref. 1). Detailed analytical data values are based on inorganic data from the STER and detailed organic data from GC/MS analysis.

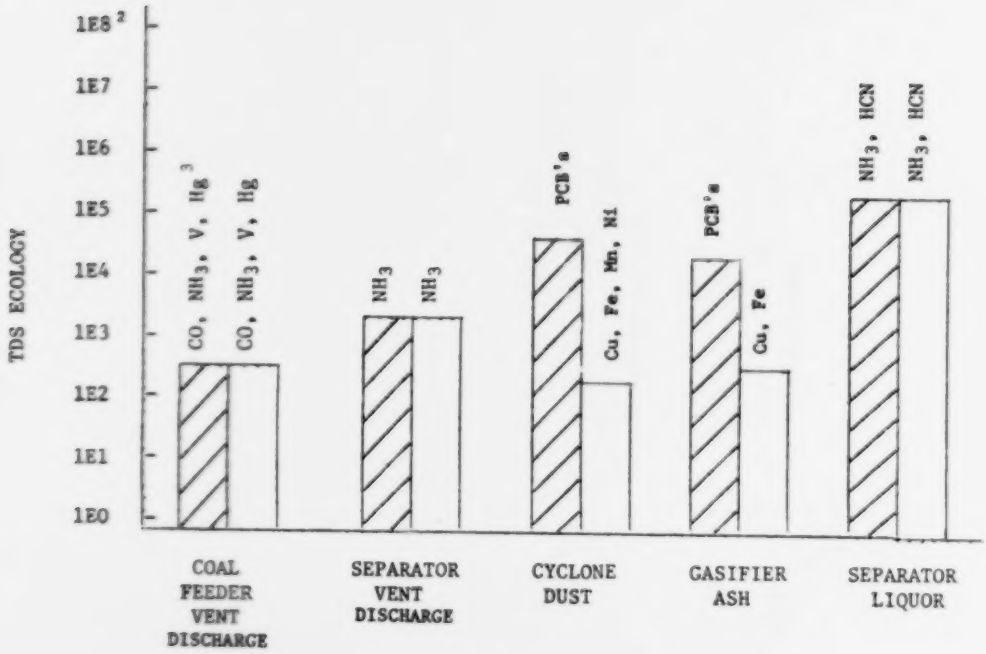
Figure 2-1 compares the TDS health values for the detailed organic analytical data and the chemical screening data for the waste streams and potential fugitive emissions from the Chapman facility. In general, values derived from the detailed organic and inorganic analytical data are from 2 to 4.5 orders of magnitude lower than values derived from the chemical screening data. However, the relative ranking of severity is similar in both cases with the exception of minor changes in the relative positions of the coal feeder vent discharge and the separator vent discharge. This indicates that TDS values for



[1]aEb = a x 10^b

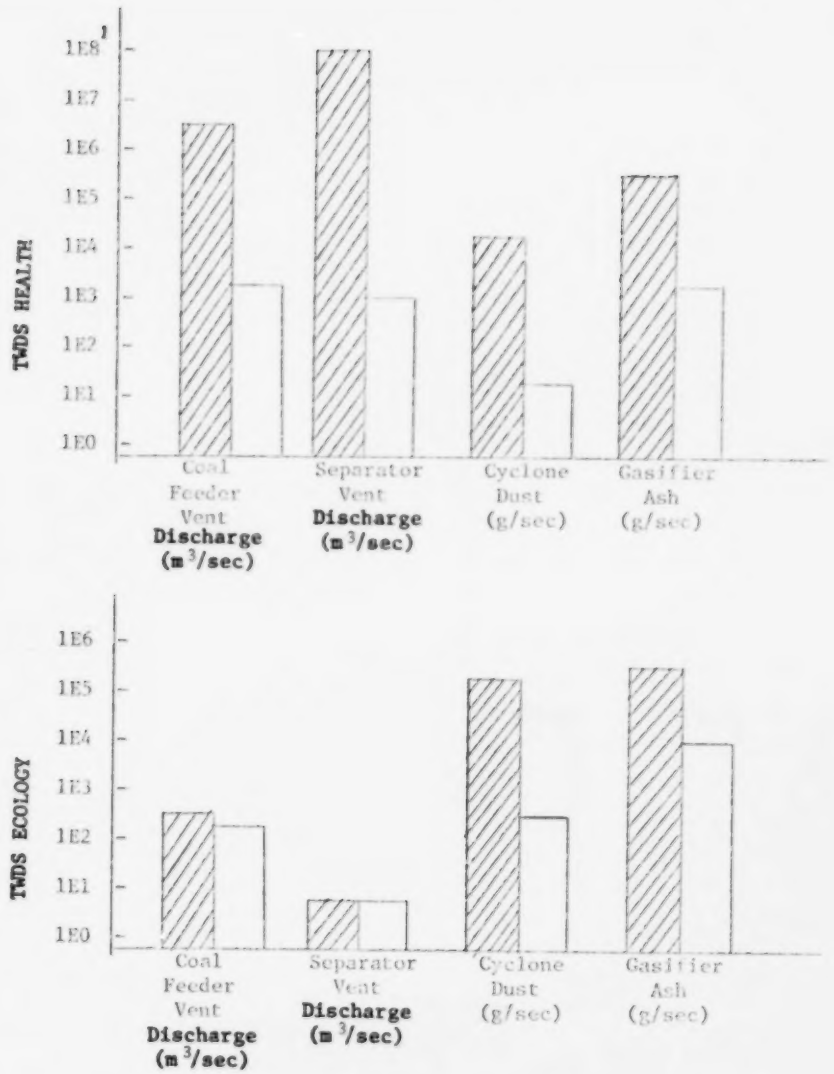
[2]Major constituents contributing to TDS

Figure 2-1. A Comparison of Total Discharge Severity Health Values and Principle Contributing Compounds from the Chemical Screening Data and the Detailed Organic Analytical Data.



[1]Ecology values were not calculated for the separator tar
[2]aEb = a x 10^b
[3]Major constituents contributing to TDS

Figure 2-2. A Comparison of the Total Discharge Severity Ecology Values and Principle Contributing Compounds from the Chemical Screening Data and the Detailed Organic Analytical Data.[1]



[1] $aEb = a \times 10^b$

Figure 2-3. A Comparison of the Total Weighted Discharge Severity Values from the Chemical Screening Data and the Detailed Analytical Data.

chemical screening data are valuable in ranking streams for health effects. Qualitatively, the principle contributing compound, benzo(a)pyrene, is the same in both cases for the coal feeder vent discharge and the separator tar. However, for the other streams much of the discharge severity from organics in the screening analysis is eliminated by the detailed organic analysis resulting in an increase in the relative contribution of inorganic compounds.

Figure 2-2 compares the TDS ecology values for the screening data and the detailed organic analytical data for the emissions and potential fugitive emissions. Because of the relatively large contributions of inorganics to the ecology values, little change is seen as a result of the detailed organic analysis. The only streams impacted are the cyclone dust and gasifier ash. The TDS ecology values for these two streams are lowered by approximately two and one-half an orders of magnitude. Except for the ash and dust, the relative ranking of the streams is not changed by the detailed analysis.

Figure 2-3 compares the TWDS health and ecology values for the chemical screening data (organics and inorganics) and the detailed organic analytical data and inorganics. The same trends are seen in the TWDS values that occurred in the TDS values. Health values are significantly lower with no change in stream ranking while ecology values are little changed except for the ash and dust.

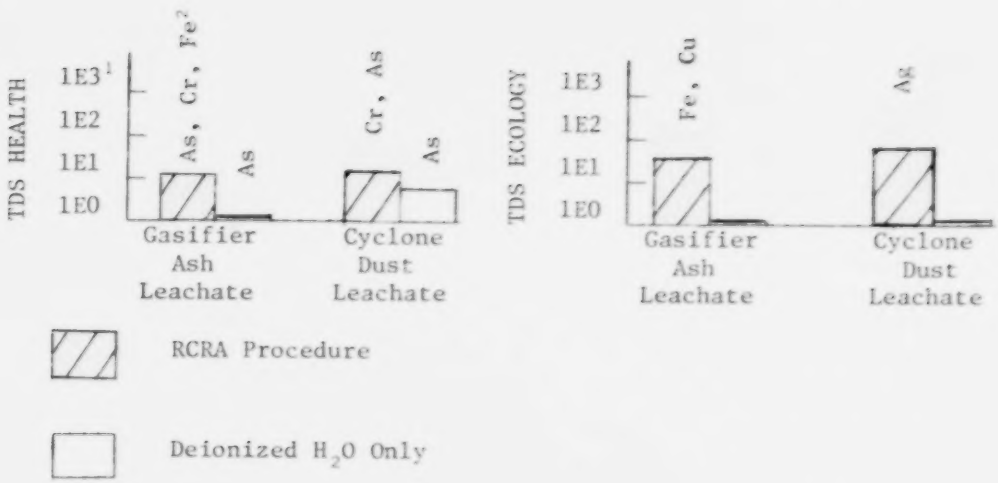
2.2 SUMMARY OF THE RESULTS OF THE GASIFIER ASH AND CYCLONE DUST LEACHATE ANALYSIS

Both the gasifier ash and the cyclone dust were leached using the Resource Conservation and Recovery Act (RCRA) procedure (Ref. 7) and using the RCRA procedure without the addition of a pH buffer. All leachates analyzed have relatively low potentials for health and ecological effects. Organic loading analyses indicate an absence of organics in the leachates and, therefore, no contribution by organics to the resulting TDS values. The spark source mass spectrometry (SSMS) results from the RCRA procedure and the RCRA procedure without buffer addition vary both quantitatively and qualitatively for trace elements. SSMS data is semi-quantitative and, therefore, trace element concentrations should be used only as estimates of actual sample concentrations. The TDS values from the SAM/1A analysis of the results along with the principle contributing elements are illustrated comparatively in Figure 2-4.

In general, the leachability of trace elements from the solids is very low. Leachability is defined as:

$$L = \frac{A}{B} \times 100$$

where: L = leachability,
A = mass of a given trace element or compound in the total leachate from 100 g of a given solid,
B = mass of a given trace element or compound in 100 g of a given solid,



[1]aEb = a x 10^b
[2]Major Constituents contributing to TDS.

FIGURE 2-4. TDS Values and Principle Contributing Elements for the Gasifier Ash Cyclone Dust Leachates.

Only arsenic in the cylone dust and arsenic, fluorine and sulfur in the gasifier ash have leachabilities greater than 10%. The ash may have been "preleachated" during the quenching process.

When the leachates are compared to RCRA specified extract limits, (Ref 7) all trace elements present with RCRA limits are significantly below those limits.

Relatively low DS values, an absence of organic loading, low concentrations of elements within RCRA limits, and low leachability of trace elements all indicate that the leachates from both the ash and dust should be given low priority as potentially harmful wastes.

2.3 SUMMARY OF THE RESULTS OF THE FEED COAL ANALYSIS

The feed coal was analyzed for trace elements by SSMS. A total of 54 trace elements were detected in the coal. Of these, Al, Ca, Fe, Mg, P, K, Se, Sr, S and Ti have mass flows in excess of 100 g/hr.

In general, the bulk of the trace element mass exiting the gasifier in the solid waste streams is found in the gasifier ash with relatively low concentrations in the cyclone dust. Fifteen elements were preferentially concentrated in the gasifier ash. These are: Al, Ba, Be, B, Ca, Co, Cu, Cd, Pb, Mg, Ni, Ru, Sc, Sn and Ti.

2.4 RECOMMENDATIONS

Specific recommendations for consideration in future Chapman gasifier STE programs fall into two categories:

- additional data needs, and
- methodology recommendations

Data Needs

In general, the short term data needs for an initial assessment have been met for the waste streams and potential fugitive emissions from the Chapman facility using Virginia bituminous feed coal. The organic and trace element characterization of the streams presented in this report, along with the data already available in the Chapman STER (Ref. 1) should be sufficient to provide preliminary guidance in the selection of a control scheme to treat process and waste streams with potential health and ecological effects. Long term (30 day) monitoring to establish process variability and data for additional coal types is required to provide support for the development of regulations. The compounds and elements listed as "principle" contributors to the TDS values for the streams and any other compouds which exceed regulatory standards should be subjected to long term monitoring in the input and output streams of any control employed.

Additional data which are needed to assess the potential health and ecological effects are:

- a characterization of the combustion products of the product gas, in order to assess the possible effects of burning the product gas,
- a characterization of the gaseous discharge from the quench liquor forced evaporator,
- a characterization of phthalates in the gasifier ash to determine if detected phthalates are artifactual,
- a detailed characterization of the polycyclic hydrocarbons including specifically the speciation of the 252 molecular weight isomeric group containing B(a)P for those streams in which B(a)P contributes the bulk of the potential health effects, and
- characterization of emissions during operation with a second coal feed to the extent necessary to identify significant changes related to coal characteristics.

Methodology Recommendations

The analytical methodologies employed for the detailed analyses were satisfactory except in the resolution of polycyclic hydrocarbons. It is recommended that samples high in polycyclics should be analyzed by a technique such as gas chromatography/mass spectrometry (GC/MS) using a liquid crystal column to provide detailed data on specific environmentally significant polycyclic hydrocarbons such as B(a)P.

The comparison of RCRA and unbuffered (deionized water) leaching procedures indicates that quantitative and qualitative differences occur in the leachates derived from the two procedures. It is recommended that solid wastes should be leached using both procedures to provide a better characterization of possible leachates entering the environment.

SECTION 3

PLANT DESCRIPTION

The Chapman gasification facility produces a low-Btu gas (5.9×10^6 J/Nm^3, 150 Btu/scf) which is used as combustion fuel for process heaters. The facility is equipped with 12 operational Chapman gasifiers. However, current fuel demands are low and are met by operating only two gasifiers at any specific time.

A block flow diagram of the Chapman facility is given in Figure 3-1. Major gaseous, liquid, and solid waste streams and process streams are indicated.

Three operations are conducted at the Chapman facility: coal handling, gasification, and gas purification (particulate removal, and gas quenching and scrubbing). They consist of one or more discrete steps, as follows:

- Coal handling - consists of delivery and storage of presized Virginia bituminous coal in hopper cars as well as conveying and storing the coal in the gasifier feed hoppers.

- Coal gasification - consists of producing raw, low-Btu (5.9×10^6 J/Nm^3, 150 Btu/scf) gas from coal using fixed-bed, atmospheric pressure, single-stage Chapman gasifiers. The coal enters the gasifier through a rotating feeder (barrel valve) and is spread across the bed by a distribution arm. Steam and air are introduced into the bottom of the gasifier and pass through a grate which distributes the gases and supports the fuel bed. Ash is collected in a water-sealed ash pan and removed by an ash plow. Pokeholes on the top of the gasifier are opened periodically to permit the insertion of rods to break up any coal agglomerates that form in the gasifier and to measure the coal-bed depth.

- Gas purification -

  - Particulate removal - consists of cyclonic removal of particulate matter from the hot, low-Btu gas. The particulate matter consists of devolatilized coal particles, tar and ash.

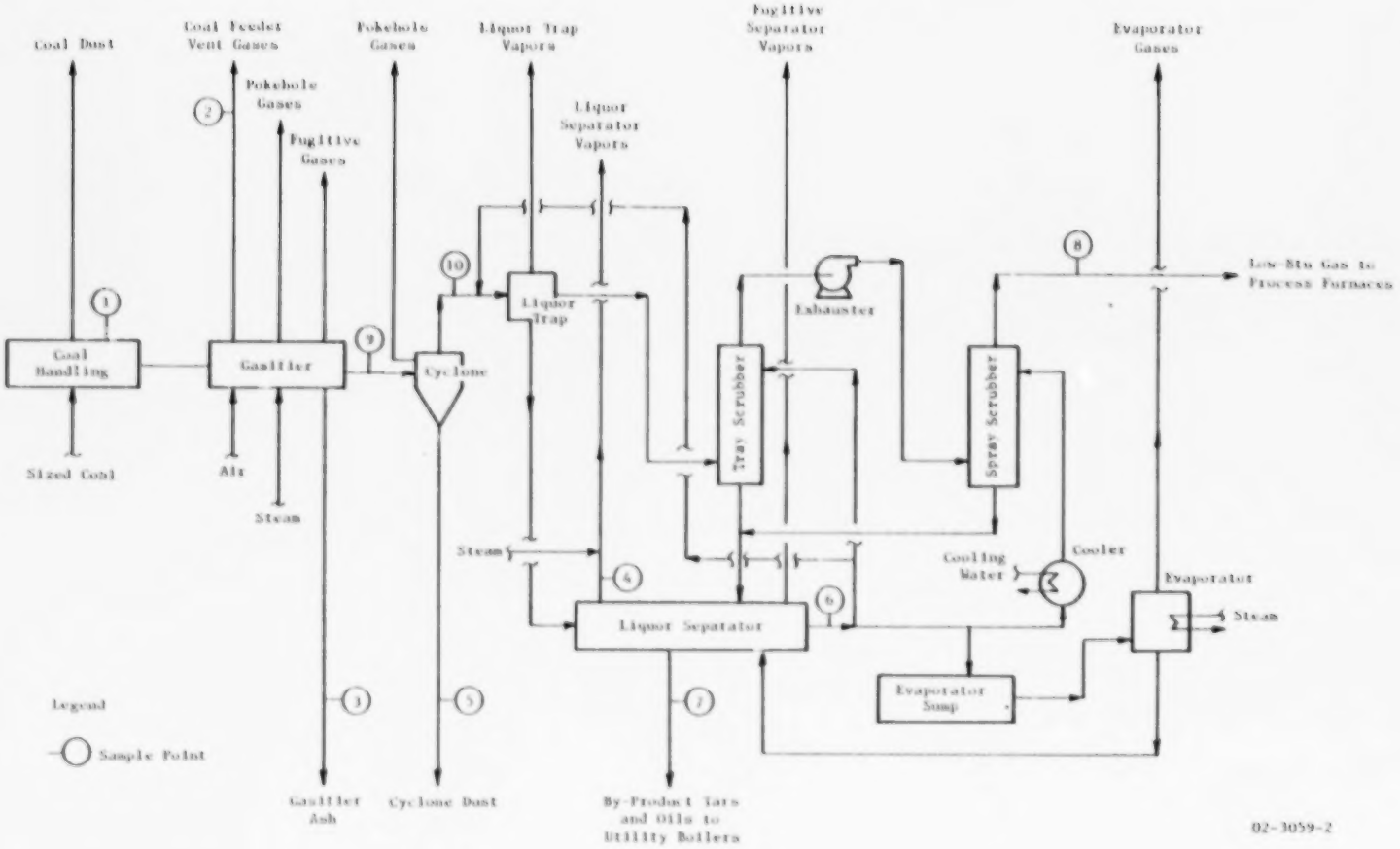


Figure 3-1. Simplified process flow diagram for the Chapman Facility showing sampling points and gaseous, liquid, and solid waste streams.[1]

[1]Source = Ref. 1.

- Gas Quenching and scrubbing - consists of removing tars and oils from the hot gas and cooling the gas to 320°K (120°F). The gas is cooled by in-line sprays followed by two tray scrubbers and a spray scrubber. Tar-laden quench liquor is sent to a tar/liquor separator where the tars settle to the bottom. The tars are removed periodically and used as an auxiliary fuel in a coal-fired boiler. The quench liquor is cooled and recycled to the gas quenching and scrubbing processes. Accumulated quench liquor is sent to a forced evaporator for treatment. Ideally, wastewater problems can be minimized by operating the gasifier so that there is no net accumulation of water during the process. During the test period, no accumulated quench liquor was sent to the evaporator for treatment.

During the test program, stream flow rate data were collected to perform a total mass balance around the plant and to estimate emission rates. Table 3-1 shows the stream flow rates and overall mass balance. Approximately 90 percent of the total input mass was accounted for in the total mass exiting the plant.

TABLE 3-1. MASS BALANCE AROUND THE CHAPMAN GASIFICATION FACILITY[1]

Input Streams	Flow Rate (kg/hr)
- Gaseous	
• Air	2772
• Steam	576
- Solid	
• Coal	1094
Total Input	4442
Output Streams	
- Gaseous	
• Coal Feeder Vent Discharge	22
• Separator Vent Discharge	194
• Product Gas	3560
- Liquid	
• By-Product Tar	109
- Solid	
• Gasifier Ash	67
• Cyclone Dust	6
Total Output	3958
(Output/Input) x 100	89%

[1] Source = Ref. 8

SECTION 4

SELECTION OF STREAMS FOR DETAILED ORGANIC ANALYSIS

Section 4 summarizes the results of the SAM/1A analysis of the solid waste leachate data and of the chemical screening data from the original STER (Ref 1) for the Chapman facility process and waste streams. In addition, a summary of the bioassay testing results for the process and waste streams is repeated from the STER for comparison with the detailed organic analysis data. Criteria for ranking the streams for potential health and ecological effects based on these results are discussed along with the streams chosen for detailed organic analysis.

4.1 SUMMARY OF THE SOURCE ANALYSIS MODEL/1A RESULTS FOR THE CHEMICAL SCREENING AND LEACHATE DATA

The Source Analysis Model/1A (SAM/1A) (Ref. 2) was used to identify and prioritize potentially harmful waste streams and potential fugitive emissions from the Chapman facility based on the chemical screening data given in "Source Test and Evaluation Report--Chapman Low-Btu Gasification," (Ref. 1) and additional data for the solid waste leachates. Major simplifying assumptions implicit in the use of the SAM/1A methodology are:

- The substances currently in the Multimedia Environmental Goals (MEG) lists (Ref. 3, 4, 5 and Table A-1) are the only ones that must be addressed at this time.
- Transport of the components in the waste streams to the external environment occurs without chemical or physical transformation of those components.
- Discharge Multimedia Environmental Goal (DMEG) values (Ref. 3, 4, 5 and Table A-1) developed for each substance are adequate for estimating acute toxicity. A DMEG is a concentration of a substance estimated not to cause adverse effect in a health or ecological receptor exposed once or intermittently for short periods, or represents control limits achievable through technology.
- The waste stream components cause no synergistic effects.

The results of the SAM/1A analyses of the chemical screening data are given in Table 4-1. The results given for those data from the Chapman STER have been recalculated to reflect current DMEG values. In addition, the organic loading is reflected in the values given for the solid waste streams. It was not taken into consideration in the STER. The separator

TABLE 4-1. RESULTS OF THE SAM/1A ANALYSIS OF THE CHEMICAL SCREENING DATA [1]

	TDS		TWDS		Organic Contribution (%)	
	Health	Ecology	Health	Ecology	Health	Ecology
Gaseous Waste Streams[2]						
Coal Feeder Vent Discharge	5E7[3]	4E2	3E6(m^3/sec)	2E1(m^3/sec)	>99.9	<0.1
Separator Vent Discharge	1E8	2E3	6E7(m^3/sec)	1E3(m^3/sec)	>99.9	<0.1
Solid Waste Streams[2]						
Cyclone Dust	4E4	1E5	6E4(g/sec)	2E5(g/sec)	>99.9	30
Gasifier Ash	2E4	3E4	4E5(g/sec)	6E5(g/sec)	>99.9	70
Solid Waste Leachates						
Cyclone Dust (RCRA)[4]	3E1	7E1			0	0
Cyclone Dust (H_2O Only)[5]	9	1E3			0	0
Gasifier Ash (RCRA)[4]	1E1	3E1			0	0
Gasifier Ash (H_2O Only)[5]	2	2E2			0	0
Potential Fugitive Emissions[2]						
Separator Liquor	3E5	2E5			>99.1	<0.1
Separator Tar	2E9				>99.9	

[1] TDS (Total Discharge Severity) and TWDS (Total Weighted Discharge Severity) values are based on DMEG values in Ref. 3, 4, 5 except when superceded by DMEG values given in Table A-1 in the Appendix.

[2] TDS and TWDS values based on data in Ref. 1.

[3] $aEb = a \times 10^b$

[4] RCRA = leachate produced by RCRA procedure (Ref. 7).

[5] H_2O Only = leachate produced by RCRA procedure but without pH buffer.

tar, treated as a solid in the STER, is here treated as a liquid. The value given for the separator tar is calculated on the basis of liquid DMEG values and assumes a density of 1.5 g/mL.

The total discharge severity values (TDS) and total weighted discharge severity values (TWDS) for all streams analyzed are greater than 1. The gaseous waste streams, solid waste streams, and potential fugitive emissions all have TDS health values in the range of 10^4 to 10^9 and TDS ecology values of 10^2 to 10^5 indicating high levels of concern for all streams analyzed. In addition, the organic components in these streams contribute more than 99% of the TDS and TWDS values for health. Therefore, the results of the SAM/1A analyses of these streams indicate that detailed analyses should be performed on the organic components of each stream.

In contrast, the solid waste leachates have TDS values in the range of 10^0 to 10^1 for health and 10^1 to 10^3 for ecology. These values indicate relatively low levels of potential effects for health and intermediate levels for ecology. The organic analyses indicate an absence of organic components in the leachates and correspondingly, no contribution by organics to the TDS values. Therefore, the results of the SAM/1A analyses of the solid waste leachates indicate that detailed organic analyses should not be performed.

4.2 SUMMARY OF THE BIOASSAY SCREENING TEST RESULTS

The bioassay screening tests used in the Chapman STE program are given in Table 4-2. All streams listed in Table 4-1, except the solid waste leachates, were subjected to bioassay screening. The results of the bioassay screening tests are summarized in Table 4-3.

Before the bioassay test results can be used with the SAM/1A analysis results to prioritize streams for further detailed analyses, they must be interpreted with respect to potential health and ecological effects. The interpretations of the bioassay results are derived from the recommendations made by the Bioassay Subcommittee formed by IERL/RTP.

The general guidelines for interpreting the bioassay test results are as follows:

- High potential effect (only one of the following results are required to give a stream a high potential effect)
  - Positive Ames test
  - Significant toxic effects noted in the RAT test
  - Toxic effects in the aquatic tests
  - Significant toxic effects noted in the soil microcosm test (i.e., samples with effects greater than or equal to the separator tar)

TABLE 4-2. BIOASSAY SCREENING TESTS AND RESPONSES[1]

Bioassay Test	Biological Response
Health Tests	
Ames	Potential mutagenicity (carcinogenicity)
WI-38	Acute cellular toxicity
RAM	Acute cellular toxicity
RAT	Acute toxicity (whole animal)
Aquatic Tests	
Fresh water (algae, daphnia, and fathead minnow) tests	Toxicity
Salt water (algae, grass shrimp, and sheepshead minnow) tests	Toxicity
Terrestrial Tests	
Soil microcosm	Toxicity (ranking only)
Plant stress ethylene	Toxicity

[1]Source = Ref. 8

TABLE 4-3. BIOASSAY TEST RESULTS FOR THE CHAPMAN COAL GASIFICATION FACILITY[1]

	Coal Feed (s)	Coal Feeder Vent Gas[a] (g)	Coal Feeder Vent Gas XAD-2 Extract[a](g)	Gasifier Ash[a](s)	Cyclone Dust[a](s)	Separator Tar(s)	Separator Vent Gas XAD-2 Extract[a](g)	Separator Liquor (l)
HEALTH TESTS								
1. Ames	SP	-	P	N	N	P	SP	N
2. Cytotoxicity[a]								
WI-38, EC_{50} (cell count, µg solid, m^3 gas/mℓ culture)	>60	-	4×10^{-4}	-	-	-	7×10^{-4}	-
RAH, EC_{50} (cell count, µg solid & liquid, m^3 gas/mℓ culture)	>1000	-	$>2 \times 10^{-4}$	>300	>1000	>1000	$>1 \times 10^{-4}$	>600
3. Rodent Acute Toxicity	M	-	-	L	M	H	-	L
LD_{50} (g sample/kg rat)	>10	-	-	>10	>10	>10	-	>10
ECOLOGICAL TESTS								
Fresh Water[b]								
Algal, EC_{50} (15 days)	-	-	-	-	-	-	-	1.0 to 0.1%
Daphnia, LC_{50} (48 hours)	-	-	-	-	-	-	-	0.11%
Fathead minnow, LC_{50} (96 hours)	-	-	-	-	-	-	-	0.02%
Salt Water[b]								
Algal, EC_{50} (12 days) filter/unfiltered	-	-	-	-	-	-	-	0.53/0.41%
Shrimp, LC_{50} (96 hours)	-	-	-	-	-	-	-	0.25%
Sheepshead minnows, LC_{50} (96 hours)	-	-	-	-	-	-	-	0.16%
Terrestrial								
Soil microcosm[c]	3	-	-	4	1	2	-	5
Plant stress ethylene	-	M	-	-	-	-	-	-

[1] Source = Ref. 1

[a] Indicates a plant waste stream

SP: Slightly positive
P: Positive
N: Negative

(g): gas, (s): solid, (l): liquid

H: High toxicity
M: Medium toxicity (*i.e.*, rats showed hair loss, eye discoloration, etc.)
L: Low toxicity (*i.e.*, no significant effects noted)

EC_{50}: Concentration at which growth was 50 percent of a control

LC_{50}: Concentration at which 50 percent of the experimental animals died

LD_{50}: Dose per kg of test animal at which 50 percent died.

[a] EC_{50}'s were calculated on the XAD-2 extract for the coal feeder and separator vent gases by:

$$EC_{50} = \left[\begin{array}{c}EC_{50} \text{ reported} \\ \text{in µℓ of extract} \\ \text{per mℓ culture}\end{array}\right] \times \left[\begin{array}{c}\text{mg of organics} \\ \text{extracted per mℓ} \\ \text{of extract}\end{array}\right] \div \left[\begin{array}{c}\text{mg of organics} \\ \text{per } Nm^3 \text{ of} \\ \text{vent gas}\end{array}\right] = Nm^3 \text{ vent gas/mℓ culture}$$

[b] EC_{50}'s and LC_{50}'s for fresh and salt water tests are presented in wt% of the sample in water.

[c] Soil microcosm tests are ranked from No. 1, the most toxic, to No. 5, the least toxic.

- Moderate potential effect

  - Slightly positive Ames test
  - Some toxic effects noted in the RAT test

- Low potential effect (all of the following results must be obtained)

  - Low cytotoxicity effects noted in the WI-38 and RAM tests
  - Low toxic effects noted in the RAT test
  - Low toxic effects noted in the soil microcosm test (i.e., samples with lower effects than the coal feedstock)

- No detectable effect (all of the following results must be obtained)

  - Negative Ames test
  - EC-50's not determined in the WI-38 and RAM tests
  - No detectable effects on plant's ethylene production

The results of the bioassay test interpretations are summarized in Table 4-4. They indicate that there may be a high potential for health and/or ecological effects associated with all of the streams except the gasifier ash. It should be emphasized that interpretation of the bioassay results is currently very subjective. However, as more data are obtained, the basis of interpretation of these results will be more defined.

4.3 STREAMS AND STREAM COMPONENTS SELECTED FOR DETAILED ORGANIC ANALYSIS

The results of the SAM/1A analyses and the bioassay screening tests indicate that all streams have a potential for health and/or ecological effects. The SAM/1A analyses also indicate that the organics in all samples except the leachates may have the greatest potential for affecting health and the environment. The SAM/1A analysis for the leachates indicates that organics do not contribute to their potential hazard. Therefore, detailed organic analysis was performed on all samples except the solid waste leachates.

TABLE 4-4. INTERPRETATION OF THE BIOASSAY TEST RESULTS ON THE CHAPMAN WASTE STREAMS AND POTENTIAL FUGITIVE EMISSIONS

Bioassay Test	Plant Waste Streams and Potential Fugitive Emissions						
	Coal Feed	Coal Feeder Vent Discharge	Gasifier Ash	Cyclone Dust	Separator Tar	Separator Vent Discharge	Separator Liquor
Health							
• Ames	M	H	ND	ND	H	M	ND
• WI-38	ND	L	-	-	-	L	-
• RAM	ND	ND	ND	ND	ND	ND	ND
• RAT	M	-	L	M	H	-	L
Freshwater							
• Algal	-	-	-	-	-	-	H
• Daphnia	-	-	-	-	-	-	H
• Fathead Minnow	-	-	-	-	-	-	H
Saltwater							
• Algal	-	-	-	-	-	-	H
• Shrimp	-	-	-	-	-	-	H
• Sheepshead Minnow	-	-	-	-	-	-	H
Terrestrial							
• Soil Microcosm	M	-	L	H	H	-	L
• Plant Stress Ethylene	-	ND	-	-	-	-	-

[1]Source = Ref. 8
-: Test not performed
H: High
M: Moderate
L: Low
ND: Not detectable

SECTION 5

RESULTS

5.1 RESULTS OF THE DETAILED ORGANIC ANALYSES

With the exception of the gasifier ash and cyclone dust, the extractable organics in all samples were fractionated using the acid-base-neutral (ABN) scheme outlined in Section 6.2. The resulting 7 fractions were analyzed by gas chromatography/mass spectrometry (GC/MS) to identify specific compounds and isomeric groups. The ash and dust extracts were analyzed without fractionation because of low total organic loadings based on total chromatographable organics and gravimetric analysis data from the Chapman STER (Ref. 1). The streams fractionated were the coal feeder vent discharge, separator vent discharge, separator liquor, and separator tar.

The purpose of the ABN fractionation scheme was to fractionate the samples into classes of compounds to facilitate compound identification by GC/MS.

The results of the GC/MS analyses following fractionation are given in Tables 5-1 through 5-12. In many cases the analytical technique did not distinguish amines from their corresponding heterocyclic isomers, therefore MEG categories 10 and 23 are not considered separately. Table 5-11 gives the MEG categories expected in each fraction and summarizes the categories actually found in each fraction for all samples analyzed. Although qualitative overlap was seen in all fractions, in general it was minimal when viewed quantitatively and did not prove detrimental to compound identification. Tables 5-2 through 5-5 show the MEG categories identified in each ABN fraction for each sample and the distribution of the total mass per fraction detected by GC/MS in each category. The tables indicate good quantitative fractionation except in fractions 1 (non-polar neutrals) and 2 (weakly polar neutrals).

It should be noted that compounds in MEG category 13, thiols, sulfates and disulfides, were not detected in the detailed organic analysis. The failure to detect these compounds as major species implies that they would not significantly impact the severity of the stream. However, future testing should include analysis for the compounds using selective detection techniques.

The fractional distribution of the total mass detected in each stream is given in Table 5-6. The separator vent discharge and separator liquor both have than 90% in their total mass in fraction 6 (phenols) with low values for all other fractions. The separator tar and coal feeder vent discharge are high in non-polar to slightly polar neutral compounds (fraction 1 and 2). In addition, the tar

also contains significant mass in fractions 3 (slightly polar neutrals) and 6 (phenols). No sample analyzed shows a significant percentage of its detected mass in fractions 4 (highly polar neutrals) or 7 (bases). All values for fractions 4 and 7 are <1% except for the coal feeder vent discharge which has 2% of its mass in fraction 7.

Table 5-7 gives the TCO and GRAV values for the screening and detailed analyses and the percent of those values detected by GC/MS. Recoveries ranged from 50% for the separator liquor to 6.6% for the separator tar.

The actual compounds with a DS >1 and the basis for the DMEG value associated with the DS values are given in Tables 5-8 through 5-12. Since the analyses are semi-quantitative, these values should be used only as an estimate of actual stream severity. A detailed listing of all compounds detected for all samples, their DS values and estimated stream concentrations, regardless of DS value or DMEG availability is given in Tables A-3 through A-8 in the Appendix.

Table 5-8 shows that the only compounds with a DS >1 for the gasifier ash are the phthalates as a group, with a DS ecology value of 4. Phthalates are common artifacts in trace level organic analysis and additional analysis should be performed to verify this result.

The MEG category containing compounds with DS values >1 for the coal feeder vent discharge (Table 5-9) is fused polycyclics. Three compounds in this cateogry were present at levels of concern for health with benzo(a)pyrene [B(a)P] contributing 99.9% of the total DS value. The analytical method used does not distinguish B(a)P from up to six isomers of the same molecular weight which elute at close to or the same retention time. The DS value assumes that the entire mass at molecular weight 252 is B(A)P. Therefore, the DS value for B(a)P should be considered a "worst case" value. The same is true for benz(a)anthracene and phenanthrene/anthracene.

Table 5-10 indicates that three MEG categories: amines, benzenes, and phenols, contain compounds with DS health values >1 for the separator vent discharge. Phenols contribute ≈90% of the total DS value for all compounds with a DS >1 in the separator vent discharge.

Recently, Research Triangle Institute has proposed revised DMEG values for phenol in water of 1.7E4 µg/L (1.7×10^4 µg/L) and 3.0E3 µg/L for health and ecology respectively, based on 1979 proposed water quality criteria (Ref 6). These values are used for the phenols listed in Tables 5-11 and 5-12.

Table 5-11 indicates that 3 compounds, all phenols, have DS health values >1 in the separator liquor. Of these compounds, 2 were EPA Concent Decree Priority Pollutants (Ref. 9). In addition, four more priority pollutants were identified which either have not been assigned DMEG values, or have DS health values <1. Seven compounds in three categories have DS ecology values >1. Phenols comprise ≈88% of the total DS ecology values for all compounds with a DS >1.

Table 5-12 shows that 15 compounds in 6 categories have DS health values >1 for the separator tar. The DS values are for a liquid assuming a density of 1.5 g/mL. Benzo(a)pyrene is the major contributing compound to the total organic DS value of the stream, contributing >99% of the value. The same limitations to the DS values for fused polycyclics discussed for the coal feeder vent discharge apply to the tar. Therefore, DS values for these compounds in the tar should be considered "worst case" values.

No compounds with DS values >1 were identified in the cyclone dust.

TABLE 5-1. DETAILED ORGANIC ANALYSIS: EXPECTED DISTRIBUTION AND ACTUAL DISTRIBUTION OF MEG CATEGORIES IN THE ABN SEPARATION SCHEME

ABN FRACTION	MEG	CATEGORIES EXPECTED [1]	MEG	CATEGORIES FOUND
1 Non-Polar Neutrals	1	Aliphatic Hydrocarbons	1	Aliphatic Hydrocarbons
			5	Alcohols
			8D	Carboxylic Acid Esters (Phthalates, Adipates)
			15	Benzenes, Substituted Benzenes
			21	Fused Polycyclic Hydrocarbons
			22	Fused Non-Alternant Hydrocarbons
			25	Heterocyclic Sulfur Compounds
2 Weakly Polar Neutrals	3	Ethers	8A	Carboxylic Acid Esters (Phthalates, Adipates)
	7	Aldehydes and Ketones		
	13	Thiols, Sulfates, Disulfides	10/23	Amines and Heterocyclic Nitrogen Compounds
	15	Benzenes, Substituted Benzenes	15	Benzenes, Substituted Benzenes
	21	Fused Polycyclic Hydrocarbons	18	Phenols
			21	Fused Polycyclic Hydrocarbons
	22	Fused Non-Alternant Hydrocarbons	22	Fused Non-Alternant Hydrocarbons
	24	Heterocyclic Oxygen Compounds	24	Heterocyclic Oxygen Compounds

(Continued)

TABLE 5-1 (Continued). DETAILED ORGANIC ANALYSIS: EXPECTED DISTRIBUTION AND ACTUAL DISTRIBUTION OF MEG CATEGORIES IN THE ABN SEPARATION SCHEME

ABN FRACTION		MEG	CATEGORIES EXPECTED	MEG	CATEGORIES FOUND
3	Moderately Polar Neutrals	18	Phenols	5	Alcohols
				7	Aldehydes and Ketones
				8A	Carboxylic Acid Esters (Phthalates, Adipates)
				9	Nitriles
				10/23	Amines and Heterocyclic Nitrogen Compounds
				18	Phenols
4	Highly Polar Neutrals	8A	Carboxylic Acid Esters (Phthalates)	1	Aliphatic Hydrocarbons
		24	Heterocyclic Oxygen Compounds	5	Alcohols
		25	Heterocyclic Sulfur Compounds	8A	Carboxylic Acid Esters (Phtalates, Adipates)
				15	Benzenes, Substituted Benzenes
				21	Fused Polycyclic Hydrocarbons
5	Methylated Acids	8	Carboxylic Acids	1	Aliphatic Hydrocarbons
				5	Alcohols
				8	Carboxylic Acids (Phtalates)
				18	Phenols
6	Phenols	18	Phenols	1	Aliphatic Hydrocarbons
				2	Phenols

(Continued)

TABLE 5-1 (Continued). DETAILED ORGANIC ANALYSIS: EXPECTED DISTRIBUTION AND ACTUAL DISTRIBUTION OF MEG CATEGORIES IN THE ABN SEPARATION SCHEME

ABN FRACTION	MEG	CATEGORIES EXPECTED	MEG	CATEGORIES FOUND
7 Bases	10/23	Amines and Heterocyclic Nitrogen Compounds	1	Aliphatic Hydrocarbons
			3	Ethers
			5	Alcohols
			10/23	Amines and Heterocyclic Nitrogen Compounds
			22	Fused Non-Alternant Hydrocarbons

[1] Source = Ref. 10.

TABLE 5-2. DETAILED ORGANIC ANALYSIS: MEG CATEGORIES IDENTIFIED BY GC/MS IN EACH ABN FRACTION FOR THE COAL FEEDER VENT DISCHARGE[1]

MEG	Category	ABN FRACTION						
No.	Name	1	2	3	4	5	6	7
1	Aliphatics(%)[2]	<1				55		
5	Alcohols (%)			6	18			<1
8	Carboxylic Acids (%)					3		
10/23	Amines & Nitrogen Heterocycles (%)			37				53
15	Benzenes (%)	14	3					
18	Phenols (%)					4	92	
21	Fused Polycyclics (%)	59	55					
22	Fused Non-Alternants (%)	7	11					
	Unknown (%)	20	31	57	82	38	8	46
Estimated Total Mass ($\mu g/m^3$)		4E4[3]	5E4	2E3	7E2	5E3	3E3	2E3

[1] XAD-2 resin, organic module rinse, probe rinse and condensate.
[2] Values given are % of the Estimated Total Mass in the Fraction.
[3] $aEb = a \times 10^b$.

TABLE 5-3. DETAILED ORGANIC ANALYSIS: MEG CATEGORIES IDENTIFIED BY GC/MS IN EACH ABN FRACTION FOR THE SEPARATOR VENT DISCHARGE[1]

MEG Category		ABN Fraction						
No.	Name	1	2	3	4	5	6	7
1	Aliphatics (%)[2]	5			3			
3	Ethers (%)							4
5	Alcohols (%)					12		
7	Aldehydes & Ketones (%)			<1				
8	Carboxylic Acids (%)	<1		45	88	22		
9	Nitrates (%)			3				
10/23	Amines & Nitrogen Heterocycles (%)							76
15	Benzenes (%)	14	60					
18	Phenols (%)			41			94	
21	Fused Polycyclics (%)	64	29					11
22	Fused Non-Alternants (%)	8	8					2
25	Sulfur Heterocycles (%)	<1						
	Unknown (%)	7	3	12	5	64	3	8
Estimated Total Mass ($\mu g/m^3$)		3E4[3]	5E4	6E3	1E3	2E2	8E6	8E3

[1]XAD-2 resin, organic module rinse, probe rinse and condensate.
[2]Values given are % of the Estimated Total Mass in the fraction.
[3]aEb = a x 10^b.

TABLE 5-4. DETAILED ORGANIC ANALYSIS: MEG CATEGORIES IDENTIFIED BY GC/MS IN EACH ABN FRACTION FOR THE SEPARATOR LIQUOR

MEG	Category	ABN Fraction						
No.	Name	1	2	3	4	5	6	7
1	Aliphatics (%)[1]					2		
5	Alcohols (%)	4		1	4	8		
8	Carboxylic Acids (%)	19	5	7		7		
10/23	Amines & Nitrogen Heterocycles (%)		19					59
15	Benzenes (%)	3						
18	Phenols (%)		72	71			89	
21	Fused Polycyclics (%)	47			74			
22	Fused Non-Alternants (%)	8						
	Unknown (%)	19	5	21	21	84	11	41
Estimated Total Mass (µg/L)		3E3[2]	1E4	1E3	1E3	1E5	2E6	3E3

[1] Values given are % of the Estimated Total Mass in the fraction.

[2] $aEb = a \times 10^{b}$

TABLE 5-5. DETAILED ORGANIC ANALYSIS: MEG CATEGORIES IDENTIFIED BY GC/MS IN EACH ABN FRACTION FOR THE SEPARATOR TAR

MEG	Category	ABN FRACTION						
No.	Name	1	2	3	4	5	6	7
1	Aliphatics (%)[1]	1			3		2	2
5	Alcohols (%)	<1		3	11			
8	Carboxylic Acids (%)	60		35	18	21		
10/23	Amines & Nitrogen Heterocycles (%)			48				72
15	Benzenes (%)	5	7					
18	Phenols (%)						70	
21	Fused Polycyclics (%)	22	52					
22	Fused Non-Alternants (%)		14					
24	Oxygen Heterocycles (%)		2					
	Unknown (%)	12	24	14	68	80	28	26
Estimated Total Mass (µg/L)		1E7[2]	2E7	7E5	2E5	9E5	6E6	5E5

[1] Values given are % of the Estimated Total Mass detected in the fraction.

[2] $aEb = a \times 10^{b}$

TABLE 5-6. DETAILED ORGANIC ANALYSIS: PERCENTAGE DISTRIBUTION OF ALL ORGANIC COMPOUNDS DETECTED BY GC/MS IN THE ABN SEPARATION SCHEME

Sample	Estimated Total Mass Detected by GC/MS	% Total Mass in each ABN Fraction						
		1	2	3	4	5	6	7
Coal Feeder Vent Discharge	1E5[1] µg/m^3	43	45	2	1	5	3	2
Separator Vent Discharge	1.7E6 µg/m^3	2	3	1	1	1	95	1
Separator Liquor	2.4E6 µg/L	1	1	1	1	6	93	1
Separator Tar	4E7 µg/L	24	41	17	1	2	14	1

[1] aEb = a x 10^b

TABLE 5-7. DETAILED ORGANIC ANALYSIS:
RECOVERY OF ORGANICS AS DETECTED BY GC/MS
IN THE ABN SEPARATION SCHEME

Sample	Estimated Mass Detected by GC/MS	TCO & GRAV[1] Chemical Screening Data	TCO & GRAV Detailed Analysis Data	% Recovered Chemical Screening Data	% Recovered Detailed Analysis Data
Coal Feeder Vent Discharge	1E5µg/m^3	7.8E5µg/m^3	8.3E5µg/m^3	12.8	12.0
Separator Vent Discharge	1.7E6µg/m^3	4.2E6µg/m^3	6.7E6µg/m^3	40	25
Separator Liquor	2.4E6µg/L	4.8E6µg/L	1.1E7µg/L	50	21.8
Separator Tar	5.1E4µg/g	7.7E5µg/g	ND[2]	6.6	--

aEb = a x 10^b

[1]Data from Ref. 1.

[2]ND = Not determined.

TABLE 5-8. DETAILED ORGANIC ANALYSIS: GASIFIER ASH - COMPOUNDS WITH A DS >1

MEG Category No.	Name	Compound	DS Land Ecology	DMEG Basis
8	Carboxylic Acids	Phthalates	4	Toxic (Aquatic)

TABLE 5-9. DETAILED ORGANIC ANALYSIS: COAL FEEDER VENT DISCHARGE - COMPOUNDS WITH A DS >1

MEG Category No.	Name	Compound	DS Air Health	DMEG Basis
21	Fused Polycyclics[1]	Phenanthrene/[2] Anthracene	2	Oncogenic
		Benzo(a)anthracene (≤5 isomers)	2E1[3]	Oncogenic, LD_{50}
		Benzo(a)pyrene (≤6 isomers)	4E4	Carcinogenic, Teratogenic

[1] "Worst Case" DMEG values are used for computing DS values for isomeric groups such as benz(a)anthracene (≤5 isomers).

[2] a/b indicates that the compound may be either a and/or b. The "worst case" DMEG value is used when two or more isomers may be present.

[3] $aEb = a \times 10^{b}$

TABLE 5-10. DETAILED ORGANIC ANALYSIS: SEPARATOR VENT DISCHARGE - COMPOUNDS WITH A DS >1

MEG No.	Category Name	Compound	DS Air Health	DMEG Basis
10	Amines	Aminotoluene	4	Toxic, Oncogenic, LD_{50}
		Aminonaphthalene/Methylquinoline[1]	2	Toxic, Carcinogenic, LD_{50}
15	Benzenes	Biphenyl/ Acenaphthene	9	Irritant, LD_{50}
18	Phenols	Phenol	2E1[2]	Toxic, Oncogenic, Mutagenic, LD_{50}
		Cresol	5E1	Toxic, LD_{50}
		C_2-Alkylphenol	7E1	Toxic, LD_{50}

[1] a/b indicates that the compound may be either a and/or b. The "worst case" DMEG value is used when two or more isomers may be present.

[2] $aEb = a \times 10^b$

TABLE 5-11. DETAILED ORGANIC ANALYSIS: SEPARATOR LIQUOR - COMPOUNDS WITH A DS >1 AND CONSENT DECREE POLLUTANTS

MEG No.	CATEGORY NAME	COMPOUND	DS WATER HEALTH	DS WATER ECOLOGY	DMEG BASIS HEALTH	DMEG BASIS ECOLOGY	CONSENT DECREE POLLUTANT
8	Carboxylic Acids	Phthalates	-	5E2[1]		Toxic(Aquatic)	Yes
18	Phenols	Phenol	4E1	2E2	Carcinogenic, Toxic, Oncogenic, Mutagenic, LD_{50}	Toxic(Aquatic)	Yes
		Cresol	6E1	3E2	Toxic, LD_{50}	Toxic(Aquatic) Taintant	No
		C_2-Alkylphenol	2E1	1E2	Toxic, LD_{50}	Toxic(Aquatic) Taintant	Yes
		C_3-Alkylphenol	-	2		Toxic(Aquatic) Taintant	No
		Dihydroxybenzene	-	3		Toxic(Aquatic) Taintant	No
21	Fused Polycyclics	Naphthalene	-	8		Toxic(Aquatic)	Yes
		Acenaphthylene	NA[2]	NA			Yes
		Benzoperylene	NA	NA			Yes

[1] aEb = a x 10^b

[2] NA = DMEG value not available

TABLE 5-12. DETAILED ORGANIC ANALYSES: SEPARATOR TAR - COMPOUNDS WITH A DS >1

MEG No.	Category Name	Compound	DS Liquid Health	DMEG Basis
8	Carboxylic Acids	Phthalates	1E2[1]	Toxic, Teratogenic, LD_{50}
		Adipates	7	LD_{50}
10	Amines	Aminonaphthalene/[2] Methylquinoline	4E1	Toxic, Carcinogenic, LD_{50}
15	Benzenes	Biphenyl/ Acenaphthene	6E1	Irritant, LD_{50}
18	Phenols	Phenol	4E1	Toxic, Oncogenic, Mutagenic, LD_{50}
		Cresol	2E2	Toxic, LD_{50}
		C_2-Alkylphenol	1E2	Toxic, LD_{50}
		C_3-Alkylphenol	1E1	Toxic, LD_{50}
		Indanol	6	Toxic, Irritant, LD_{50}
		Naphthol	4E1	Toxic, LD_{50}
		Phenylphenol/ Acenaphthol	5	Toxic, Carcinogenic, LD_{50}
19	Fused Polycyclics[3]	Phenanthrene/ Anthracene	1E2	Oncogenic
		Benz(a)anthracene (≤5 isomers)	1E3	Oncogenic, LD_{50}
		Benzo(a)pyrene (≤6 isomers)	3E6	Carcinogenic, Teratogenic
23	Nitrogen Heterocycles	Quinoline	3E1	Irritant, LD_{50}

[1] $aEb = a \times 10^b$

[2] a/b indicates that the compound may be either a and/or b. The "worst case" DMEG value is used when two or more isomers may be present.

[3] "Worst Case" DMEG values are used for computing the DS values for isomeric groups such as benz(a)anthracene (≤5 isomers).

5.2 RESULTS OF THE FEED COAL, SOLID WASTE, AND SOLID WASTE LEACHATE TRACE ELEMENT AND ORGANIC LOADING ANALYSES

5.2.1 SOLID WASTES

The feed coal and solid wastes were analyzed for trace elements using spark source mass spectrometry (SSMS). The trace element concentration data for the gasifier ash and cyclone dust is given in the Chapman STER (Ref. 1). Elements with a DS value >1 for the coal, ash, and dust are given in Tables 5-13 through 5-15. It is assumed that any phosphorous detected is present as phosphate. If phosphorous were present in its elemental form DS values for ecology would be significantly higher. All elements detected in the feed coal and their concentrations are given in Table A-13 in the Appendix.

Table 5-13 shows that the feed coal contains one element, iron, with a DS health value >1 (DS = 3.3). Iron contributes 60% of the total feed coal trace element DS health value of 5.5. Five elements have DS ecology values >1 with Cd, Fe, Ni, Se and Ti contributing ~88% of the total feed coal trace element DS ecology value of ≈4.1E1.

Table 5-14 shows that the gasifier ash contains 4 elements, barium, beryllium, iron, and selenium with DS health values >1. Of these elements, iron contributes approximately 81% of the total trace element DS health value of 44. Eleven elements have DS ecology values >1 with copper and iron contributing ≈68% of the total trace element DS ecology value of ≈4.4E2.

Table 5-15 shows that 3 elements in the cyclone dust have DS health values >1. Iron, manganese and nickel contribute ≈68% of the total trace element DS value of 19. Five elements have DS ecology values >1 with copper, iron, manganase and nickel contributing more than 99% of the total trace element DS ecology value of ≈2.0E2.

The mass flows of the trace elements entering the gasifier from the feed coal and emitted in the ash and dust are given in Table 5-16. In general, the bulk of the trace element mass exiting the gasifier in the solid waste streams is found in the gasifier ash with relatively low trace element concentrations in the cyclone dust. No element detected in the dust is emitted at more than 5.5% of its measured input flow rate. Of 54 elements detected in the coal, Al, Ba, Be, Bu, Ca, Co, Cu, Gd, Li, Mg, Nb, Rb, Sc, Sn and Ti were preferentially concentrated in the ash. These elements have apparent values greater than or equal to 100% of their measured input values. Apparent values greater than 100% are possible due to the semiquantitative nature of SSMS analysis. An additional 10 elements have emission flow rates of 50-99% of their input flows and 6 have rates of 10-49%. Twenty elements detected in the coal were not detected in the ash or dust. Elements with input concentrations not accounted for in the ash or dust such as sulfur and phosphorous are probably concentrated in the gaseous and liquid streams.

TABLE 5-13. ELEMENTS WITH A DS >1 FOR THE FEED COAL

Element[1]	DS		DMEG BASIS	
	Health	Ecology	Health	Ecology
Cadmium	--	3.5		Toxic (Aquatic, Plants)
Iron (as Fe^{++})	3.3	2.0E1[2]	Drinking water standard	Toxic (Aquatic)
Nickel	--	5.0		Toxic (Aquatic, Plants), LC_{50} (Aquatic)
Selenium	--	1.4		Toxic (Aquatic, Cattle, Plants)
Titanium	--	6.3		Toxic (Aquatic), TLm 96
Total[3]	5.35	4.1E1		

[1] All DS values are based on the DMEG value for the elemental form unless otherwise specified.

[2] $aEb = a \times 10^b$

[3] Includes elements with a DS <1

TABLE 5-14. ELEMENTS WITH A DS >1 FOR THE GASIFIER ASH

	DS[1]		DMEG BASIS	
Element[2]	Health	Ecology	Health	Ecology
Aluminum	--	2E1[3]		Toxic (Plants)
Antimony	--	5		Toxic (Aquatic), LC_{50} (Aquatic)
Barium	2	4	Toxic, Teratogenic, LD_{50}	Toxic (Aquatic), LC_{50} (Aquatic)
Beryllium	2	--	Toxic, Carcinogenic. LD_{50}	
Cadmium	--	5E1		Toxic (Aquatic, Plants)
Calcium	--	2E1		Toxic (Aquatic), LC_{50} (Aquatic)
Copper	--	1E2		Toxic (Aquatic, Plants), LC_{50} (Aquatic)
Iron(as Fe^{++})	3	2E2	Drinking water standard	Toxic (Aquatic)
Lead	--	2		Toxic (Aquatic, Plants)
Selenium	3	6	Toxic, Irritant, LC_{50}, LC_{LO}	Toxic (Aquatic, Cattle, Plants)
Titanium	--	2E1		Toxic (Aquatic), LC_{50} (Aquatic)
Uranium	--	4		Toxic (Aquatic), LC_{50} (Aquatic)
Total[4]	4.4E1	4.4E2		

[1] Data used for calculating DS values are from Ref. 1.
[2] All DS values are based on the DMEG value for the elemental form unless otherwise specified.
[3] aEb = a x 10^b
[4] Includes elements with a DS <1.

TABLE 5-15. ELEMENTS WITH A DS >1 FOR THE CYCLONE DUST

Element[2]	DS[1]		DMEG BASIS	
	Health	Ecology	Health	Ecology
Copper	--	9E1[3]		Toxic (Aquatic, Plants), LC_{50}
Iron (as Fe^{++})	7	4E1	Drinking water standard	Toxic (Aquatic)
Lead	--	6		Toxic (Aquatic, Plants)
Manganese	4	1E1	Toxic, Irritant, LD_{50}	
Nickel	2	5E1	Toxic, Allergenic, Carcinogenic	Toxic (Aquatic, Plants), LC_{50} (Aquatic)
Total[4]	1.9E1	2.0E2		

[1] Data used for calculating DS values are from Ref. 1.
[2] All DS values are based on the DMEG values for the elemental form unless otherwise specified.
[3] aEb = a x 10^b
[4] Includes elements with a DS <1.

TABLE 5-16. DISTRIBUTION OF TRACE ELEMENTS (BY SSMS) IN THE SOLID WASTE STREAMS COMPARED TO THE FEED COAL

ELEMENT	COAL INPUT[1] (g/hr)	ASH OUTPUT (g/hr)	% ASH/COAL	DUST OUTPUT (g/hr)	% DUST/COAL	TOTAL % ASH & DUST
Aluminum	110	200	180	0.6	0.005	180
Antimony	ND[2]	13	?[3]	0.6	?	?
Arsenic	2.2	<0.03	1.4	<0.002	0.09	1.5
Barium	120	130	110	2.9	2.4	110
Beryllium	<0.1	0.7	>700	ND	0	>700
Bismuth	ND	ND	-	ND	-	-
Boron	1.1	1.3	120	0.04	3.6	120
Bromine	0.4	ND	0	ND	0	0
Cadmium	0.8	<0.6	<75	ND	0	<75
Calcium	>1100	3300	<300	12	<1.1	300
Cerium	ND	6	?	0.1	?	?
Cesium	65	ND	0	ND	0	0
Chlorine	15	ND	0	ND	0	0
Chromium	28	2	7.1	0.2	0.7	7.8
Cobalt	2.2	3.3	150	0.02	0.9	150
Copper	15	67	450	5.2	35	480
Dysprosium	2.2	<ND	0	ND	0	0
Erbium	1	ND	0	ND	0	0
Europium	0.7	ND	0	ND	0	0
Fluorine	≈86	<13	<15	0.6	<0.7	<16
Gadolinium	1.1	3.3	300	<0.06	<5.5	<305
Gallium	8.8	ND	0	ND	0	0
Germanium	0.7	ND	0	ND	0	0
Gold	≤.1	ND	0	ND	0	0
Hafnium	ND	ND	-	ND	-	-
Holmium	1.1	ND	0	ND	0	0
Iodine	2.2	ND	0	ND	0	0
Iridium	ND	ND	0	ND	0	0
Iron	>1100	670	<61	12	<1.1	<62
Lanthanum	46	6.7	15	0.1	0.2	15
Lead	5.5	1.3	24	0.3	5.5	30
Lithium	3.3	5	150	0.01	0.3	150
Lutecium	ND	ND	-	ND	-	-
Magnesium	130	400	310	2.9	2.2	310
Manganese	14	ND	0	1.2	8.6	8.6
Molybdenum	3.3	ND	0	ND	0	0
Neodymium	27	ND	0	ND	0	0
Nickel	11	ND	0	0.6	5.5	5.5
Niobium	.3	1.3	430	ND	0	430

(Continued)

TABLE 5-16 (Continued). DISTRIBUTION OF TRACE ELEMENTS (BY SSMS) IN THE WASTE STREAMS COMPARED TO THE FEED COAL

ELEMENT	COAL INPUT (g/hr)	ASH OUTPUT (g/hr)	% ASH/COAL	DUST OUTPUT (g/hr)	% DUST/COAL	TOTAL % ASH & DUST
Osmium	ND	ND	-	ND	-	-
Palladium	ND	ND	-	ND	-	-
Phosphorus	>1100	53	<4.8	23	<2.1	<6.9
Platinum	ND	ND	-	ND	-	-
Potassium	>1100	670	<61	23	2.1	<63
Praseodymium	5.5	ND	-	ND	-	-
Rhenium	ND	ND	-	ND	-	-
Rhodium	ND	ND	-	ND	-	-
Rubidium	4.4	1300	29000	0.02	0.5	29000
Ruthenium	ND	ND	-	ND	-	-
Samarium	5.5	ND	0	ND	0	0
Scandium	3.3	3.3	100	0.01	0.3	100
Selenium	5.5	2	36	ND	0	36
Silicon	>1100	470	<43	12	1.1	<44
Silver	0.9	ND	0	ND	0	0
Sodium	94	ND	0	ND	0	0
Strontium	175	130	74	ND	0	74
Sulfur	690	67	9.7	1.7	0.2	10
Tantalum	ND	ND	-	ND	-	-
Tellurium	ND	ND	-	ND	-	-
Terbium	0.2	ND	0	ND	0	0
Thallium	ND	ND	-	ND	-	-
Thorium	11	ND	0	ND	0	0
Thulium	ND	ND	-	ND	-	-
Tin	1	20	2000	ND	0	2000
Titanium	1100	200	18	1.2	0.1	18
Tungsten	ND	ND	-	ND	-	-
Uranium	4.4	27	610	0.1	2.3	610
Vanadium	21	2	9.5	0.1	0.5	10
Ytterbium	ND	ND	-	ND	-	-
Yttrium	36	<1.3	<3.6	0.06	0.2	<3.8
Zinc	7.7	ND	0	ND	0	0
Zirconium	71	6	8.5	0.2	0.3	8.8

[1]Coal input = 1094 kg/hr.
[2]ND = Not detected; detection limits are - coal - 0.1 g/hr, ash = 0.007 g/hr, dust = 0.0006 g/hr. Absolute detection limit = 0.1 µg/g.
[3]Element detected in waste stream but not detected in coal.

5.2.2 SOLID WASTE LEACHATES

The gasifier ash and cyclone dust were leached by RCRA procedures and by RCRA procedures without the addition of a pH buffer (H_2O Only) (Section 6.1.1). The organic loading data from TCO and GRAV analyses for both samples indicate no detectable organic loadings in the leachates and, therefore, no contribution to the DS values by organics. The results of the organic analyses are summarized in Tables A-9 and A-10 in the Appendix.

Trace elements with DS values >1 in the ash and dust leachates are listed in Tables 5-17 and 5-18. The concentrations of all trace elements analyzed for, regardless of DS value, are given in Tables A-11 and A-12 in the Appendix.

Table 5-17 shows that both quantitative and qualitative differences were found between the RCRA and H_2O Only leachates for the gasifier ash. The major difference effecting the DS values for health is the concentrations of chromium and iron. Chromium and iron contribute ≈64% of the total DS value of 12 for the RCRA leachate. Only arsenic has a DS health value >1 (DS=1.5) in the H_2O Only leachate. For ecology, iron and copper, which were not detected in the H_2O Only leachate, contribute ≈100% of the total DS value of 29 for the RCRA leachate. No element has a DS ecology value >1 in the H_2O Only leachate.

Table 5-18 indicates that similar qualitative and quantitative differences were found between the two leachates from the cyclone dust. Chromium, not detected in the H_2O Only leachate, contributes ≈72% of the total DS health value of 33 for the RCRA leachate while arsenic (DS=9) is the only compound with a DS health value >1 in the H_2O Only leachate. Silver and copper contribute ≈100% of the ecology value of 74 for the RCRA leachate. No element has a DS ecology value >1 in the H_2O only leachate.

In general, all leachates have relatively low DS values for health and ecology. The recoveries for the trace elements in the leachates when compared to the solid concentrations are given in Tables 5-19 and 5-20. In general, the data indicate relatively low leachability for both the ash and dust. Leachability is used to describe the soluability of a compound or trace element as determined by leaching procedures. Leachability is defined as:

$$L = \frac{A}{B} \times 100$$

where:

L = leachability

A = mass of a given trace element or compound in the total leachate from 100 g of a given solid

B = mass of a given trace element or compound in 100 g of a given solid

TABLE 5-17. ELEMENTS WITH A DS >1 FOR THE GASIFIER ASH LEACHATES

Element[1]	DS HEALTH		DS ECOLOGY		DMEG BASIS	
	RCRA	H_2O Only	RCRA	H_2O Only	Health	Ecology
Arsenic	4*	1.5*	<1	<1	Toxic, LD_{50}	
Chromium (as Cr^{+6})	3.8*	ND[2]	<1	ND	Toxic, LD_{50} Carcinogenic	
Copper	<1	ND	7.6	ND		Toxic (Aquatic, Plants), LC_{50}
Iron (as FE^{++})	3.2	ND	1.9E1[3]	ND	TLV	
Total[4]	1.2E1	1.6	2.9E1	5.5E-1		

[1] All DS values are based on the DMEG values for the elemental form unless otherwise specified.

[2] ND = element not detected or below blank concentration.

[3] aEb = a x 10^b

[4] Includes elements with a DS <1.

* DS value based on DMEG value given in Table A-1.

TABLE 5-18. ELEMENTS WITH A DS >1 FOR THE CYCLONE DUST LEACHATES

Element[1]	DS HEALTH		DS ECOLOGY		DMEG BASIS	
	RCRA	H_2O Only	RCRA	H_2O Only	Health	Ecology
Arsenic	9.0*	9.0*	<1	<1	Toxic, LD_{50}	
Chromium (as Cr^{+6})	2.3E1[2]*	ND[3]	<1	ND	Toxic, LD_{50}, Carcinogenic	
Copper	<1	ND	5.1*	ND		Toxic (Aquatic, Plants), LC_{50}
Silver	<1	ND	6.7E1*	ND		Toxic (Aquatic), LC_{50}
Total[4]	3.3E1	9	7.4E1	1.1		

[1] All DS values based on the DMEG values for the elemental forms unless otherwise specified.

[2] aEb = a x 10^b

[3] ND = element not detected or below blank concentration

[4] Includes elements with a DS <1.

* DS value based on DMEG value given in Table A-1.

TABLE 5-19. RECOVERY OF TRACE ELEMENTS (BY SSMS) IN THE CYCLONE DUST LEACHATES

ELEMENT	SOLID CONCENTRATION (μg/g)	LEACHATE CONCENTRATION[1] (μg/g solid) RCRA	H_2O ONLY	% LEACHATE/SOLID RCRA	H_2O ONLY
Aluminum	100	≤BC[2]	≤8	0	≤8
Antimony	100	ND[3]	ND	0	0
Arsenic	<0.4	≤0.4	0.4	≤100	100
Barium	500	6	ND	1.2	0
Beryllium	ND	ND	ND	-	0
Bismuth	ND	ND	ND	-	-
Boron	7	0.04	≤BC	0.6	0
Bromine	ND	≤BC	0.8	-	?[4]
Cadmium	ND	ND	ND	-	-
Calcium	2000	≤120	≤BC	6	0
Cerium	20	ND	ND	-	-
Cesium	ND	ND	ND	-	-
Chlorine	ND	6	40	?	?
Chromium	30	≤0.2	≤BC	≤0.7	0
Cobalt	3	0.06	≤BC	2	0
Copper	900	0.4	≤BC	0.04	0
Dysprosium	ND	ND	ND	-	-
Erbium	ND	ND	ND	-	-
Europium	ND	ND	ND	-	-
Fluorine	100	≤BC	≤BC	0	0
Gadolinium	ND	ND	ND	-	-
Gallium	<10	≤0.6	ND	≤6	0
Germanium	ND	ND	ND	-	-
Gold	ND	0.6	ND	?	-
Hafnium	ND	ND	ND	-	-
Holmium	ND	ND	ND	-	-
Indium	ND	ND	ND	-	-
Iodine	ND	ND	ND	-	-
Iridium	ND	ND	ND	-	-
Iron	ND	<BC	ND	-	-
Lanthanum	20	ND	ND	0	0
Lead	60	<BC	≤BC	0	0
Lithium	2	0.18	ND	9	0
Lutecium	ND	ND	ND	-	-
Magnesium	500	8	6	1.6	1.2
Manganese	200	1.8	0.06	0.9	0.03
Molybdenum	ND	≤200	≤BC	?	-
Neodynum	ND	ND	ND	-	-
Nickel	100	0.6	≤BC	0.6	0
Niobium	ND	ND	ND	-	-

(Continued)

TABLE 5-19 (Cont'd). RECOVERY OF TRACE ELEMENTS (BY SSMS) IN THE CYLONE DUST LEACHATES

ELEMENT	SOLID CONCENTRATION (µg/g)	LEACHATE CONCENTRATION[1] (µg/g solid) RCRA	H_2O ONLY	% LEACHATE/SOLID RCRA	H_2O ONLY
Osmium	ND	ND	ND	-	-
Palladium	ND	ND	ND	-	-
Phosphorous	8000	<BC	10	0	0.1
Platinum	ND	ND	ND	-	-
Potassium	4000	16	140	0.4	3.5
Praseodymium	ND	ND	ND	-	-
Rhenium	ND	ND	ND	-	-
Rhodium	ND	ND	ND	-	-
Rubidium	3	ND	<BC	0	0
Ruthenium	2000	ND	ND	0	0
Samarium	ND	ND	ND	-	-
Scandium	2	<BC	ND	0	0
Selenium	ND	ND	ND	-	-
Silicon	2000	<BC	>196	0	>9.8
Silver	ND	<0.04	ND	?	-
Sodium	ND	10	>80	?	?
Strontium	80	2	<BC	2.5	0
Sulfur	300	8	4	2.7	1.3
Tantalum	ND	ND	ND	-	-
Tellurium	ND	ND	ND	-	-
Terbium	ND	ND	ND	-	-
Thallium	ND	ND	ND	-	-
Thorium	ND	ND	<0.2	-	?
Thulium	ND	ND	ND	-	-
Tin	ND	ND	ND	-	-
Titanium	200	<BC	<BC	0	0
Tungsten	ND	ND	ND	-	-
Uranium	ND	ND	<0.2	-	?
Vanadium	20	ND	ND	0	0
Ytterbium	ND	ND	ND	0	0
Yttrium	10	ND	ND	-	-
Zinc	ND	<BC	<BC	-	-
Zirconium	30	ND	ND	0	0

[1]Leachate concentrations are calculated on the basis of grams of an element in the leachate per gram of solid leached.
[2]<BC = less than or equal to the blank concentration.
[3]ND = not detected. Detection limits = 0.1 µg/g for the solid, 0.04 µg/g for the leachates.
[4]? = element detected in leachate but not in solid.

TABLE 5-20. RECOVERY OF TRACE ELEMENTS (BY SSMS) IN THE GASIFIER ASH LEACHATES

ELEMENT	SOLID CONCENTRATION (µg/g)	LEACHATE CONCENTRATION[1] (µg/g solid) RCRA	H_2O ONLY	% LEACHATE/SOLID RCRA	H_2O ONLY
Aluminum	3000	≤BC[2]	≤BC	0	0
Antimony	200	ND[3]	ND	0	0
Arsenic	<0.4	0.2	0.06	>50	>15
Barium	2000	40	≤BC	2	0
Beryllium	10	ND	ND	0	0
Bismuth	ND	ND	ND	-	-
Boron	20	0.4	0.06	2	0.3
Bromine	ND	≤BC	0.4	-	4
Cadmium	<9	ND	ND	0	0
Calcium	50000	≥120	≥120	≥0.2	≥0.2
Cerium	90	≤0.02	≤BC	≤0.02	0
Cesium	ND	ND	ND	-	-
Chlorine	ND	4	8	?	?[4]
Chromium	30	<0.06	≤BC	<0.2	0
Cobalt	ND	≤BC	≤BC	0	0
Copper	1000	0.6	≤BC	0.06	0
Dysprosium	ND	ND	ND	-	-
Erbium	ND	ND	ND	-	-
Europium	ND	ND	ND	-	-
Fluorine	<200	≈60	≤BC	>30	0
Gadolinium	ND	ND	ND	-	-
Gallium	50	ND	ND	0	0
Germanium	7000	0.08	ND	0.001	0
Gold	ND	0.04	ND	?	-
Hafnium	ND	ND	ND	-	-
Holmium	ND	ND	ND	-	-
Iodine	ND	ND	ND	-	-
Iridium	ND	ND	ND	-	-
Iron	10000	100	≤BC	1	0
Lanthanum	100	ND	ND	0	0
Lead	300	ND	ND	0	0
Lithium	70	ND	ND	0	0
Lutecium	ND	ND	ND	-	-
Magnesium	6000	>199	20	>3.3	0.3
Manganese	ND	2	0.02	?	?
Molybdenum	ND	≤BC	≤BC	-	-
Neodynum	ND	ND	ND	-	-
Nickel	ND	BC	BC	-	-
Niobium	20	ND	ND	0	0

(Continued)

TABLE 5-20 (Cont'd). RECOVERY OF TRACE ELEMENTS (BY SSMS) IN THE GASIFIER ASH LEACHATES

ELEMENT	SOLID CONCENTRATION (µg/g)	LEACHATE CONCENTRATION (µg/g solid) RCRA	LEACHATE CONCENTRATION (µg/g solid) H_2O ONLY	% LEACHATE/SOLID RCRA	% LEACHATE/SOLID H_2O ONLY
Osmium	ND	ND	ND	-	-
Palladium	ND	ND	ND	-	-
Phosphorous	800	BC	2	0	0.3
Platinum	ND	ND	ND	-	-
Potassium	10000	100	18	1	0.2
Praseodymium	ND	ND	ND	-	-
Rhenium	ND	ND	-	-	-
Rhodium	ND	ND	ND	-	-
Rubidium	20000	0.06	0.06	0.0003	0.0003
Ruthenium	50	ND	ND	0	0
Samarium	ND	ND	ND	-	-
Scandium	50	$\leq$0.02	$\leq$BC	$\leq$0.04	0
Selenium	30	$\overline{}$0.04	$\overline{\leq}$BC	$\overline{}$0.1	0
Silicon	ND	140	$\overline{}$2	?	?
Silver	ND	ND	ND	-	-
Sodium	ND	40	4	?	?
Strontium	2000	60	2	3	0.1
Sulfur	1000	>194	$\underline{\leq}$BC	>19	0
Tantalum	ND	ND	ND	-	-
Tellurium	ND	ND	ND	-	-
Terbium	ND	ND	ND	-	-
Thallium	ND	ND	ND	-	-
Thorium	ND	ND	$\leq$0.2	-	-
Thulium	ND	ND	$\overline{}$ND	-	-
Tin	ND	ND	ND	-	-
Titanium	3000	2	$\overline{\leq}$BC	0.07	0
Tungsten	ND	ND	$\overline{}$ND	-	-
Uranium	400	ND	$\underline{\leq}$0.14	0	0.04
Vanadium	30	ND	ND	0	0
Ytterbium	ND	ND	ND	-	-
Yttrium	<20	ND	ND	0	0
Zinc	ND	$\overline{\leq}$BC	20	-	?
Zirconium	90	$\overline{}$ND	ND	0	0

[1]Leachate concentrations are calculated on the basis of µg of an element in the leachate per gram of solid leached.
[2]$\overline{\leq}$BC = less than or equal to the blank concentration.
[3]$\overline{}$ND = not detected. Detection limits = 0.1 µg/g for the solid, 0.04 µg/g for the leachates.
[4]? = element detected in leachate but not in solid.

Of 30 trace elements detected in the cyclone dust (Table 5-19) only arsenic has a leachability of greater than 10% for either procedure (leachability ≈100%). An additional 8 elements have leachabilities of 1-10% using the RCRA procedure. An additional 5 elements are in the 1-10% range using the H_2O Only procedure. Fourteen of the 30 elements detected in the dust were either not detected in the RCRA leachate or are present at below their corresponding blank concentrations. Twenty of the 30 elements detected in the dust were either not detected in the H_2O Only leachate or are present at below their corresponding blank concentrations.

Of 33 elements detected in the gasifier ash (Table 5-20), arsenic, fluorine and sulfur are the only elements with leachabilities of >10%. Arsenic showed leachabilities of 50% and 15% for the RCRA and H_2O Only leachates respectively. Fluorine has a leachability of >30% for the RCRA leachate but was below the blank concentration in the H_2O Only leachate. Similarly, sulfur has a leachability of >19% in the RCRA leachate, but was not detected in the H_2O Only leachate. An additional 5 elements have leachabilities in the 1-10% range using the RCRA procedure. Arsenic is the only element with a leachability greater than 1% using the H_2O Only procedure. Seventeen of 33 elements detected in the ash were either not detected in the RCRA leachate or are present at below their corresponding blank concentrations. Twenty-four of the 33 elements detected in the ash were either not detected in the H_2O Only leachate or are present at below their corresponding blank concentrations.

Table 5-21 indicates that all elements detected in the leachates with RCRA extract limits (Ref. 7) are well below those limits.

Relatively low DS values for health and ecology combined with an absence of organic loadings, low concentrations of elements with RCRA limits, and low leachabilities of trace elements in general indicate that the leachates from both the gasifier ash and the cyclone dust should be given low priority for causing potential health or ecological effects.

TABLE 5-21. COMPARISON OF SOLID WASTE LEACHATES AND RCRA EXTRACT LIMITS

ELEMENT	RCRA LIMITS (5/18/80) (mg/L)	GASIFIER ASH LEACHATE RCRA (mg/L)	GASIFIER ASH LEACHATE DI H_2O (mg/L)	CYCLONE DUST LEACHATE RCRA (mg/L)	CYCLONE DUST LEACHATE DI H_2O (mg/L)
As	5.0	0.01	0.003	0.02	0.02
Ba	100	2.0	≤BC[1]	<0.3	<0.002
Cd	1.0	<0.002	<0.002	<0.002	<0.002
Cr	5.0	≤0.003	<0.002	<0.008	≤BC
Pb	5.0	0.010	≤BC	≤BC	≤BC
Se	1.0	0.002	≤BC	<0.002	<0.002
Ag	5.0	<0.002	<0.002	≤0.002	<0.002

[1] ≤BC = less than or equal to the blank concentration.

SECTION 6

ANALYTICAL METHODS

Section 6 summarizes the leaching and analytical procedures used in the preparation and analysis of the gasifier ash, cyclone dust and feed coal. In addition, the acid-base-neutral fractionation scheme used for the detailed organic analyses is presented along with flow sheets illustrating the fractionation scheme. GC/MS analysis and quantification of organic compounds are discussed.

6.1 TRACE ELEMENT AND ORGANIC LOADING ANALYSES OF THE SOLID WASTE LEACHATES AND FEED COAL

The feed coal was analyzed as a solid for trace elements using spark source mass spectrometry (SSMS).

Two leachates each were produced for both the gasifier ash and the cyclone dust. One leachate was produced using RCRA procedures (Ref. 4). A second leachate (H_2O Only) was produced using RCRA procedures without the addition of a pH buffer. The four leachates were analyzed for trace elements by SSMS and for organic loading by total organic carbon analysis (TOC), total chromatographable organics analysis (TCO), gravimetric analysis (GRAV) and infrared analysis (IR) of the GRAV residues. A blank leachate produced by RCRA procedures was analyzed as a control for SSMS and a second blank leachate produced without a pH buffer was analyzed along with the RCRA control leachate as a control for the organic analysis.

The analytical procedures used for the ash, dust, and coal are detailed in sections 6.1.1 - 6.1.7.

6.1.1 LEACHING METHODS

RCRA leachings were performed by weighing 100 g. of gasifier ash and 100 g. of a cyclone dust composite sample consisting of equal amounts of three samples taken on the same day into amber glass jars. Sixteen hundred milliliters of deionized water were added to the jar. The initial pH was recorded and the solution was titrated to a pH of 5 with 0.5 N acetic acid. The solution was continuously stirred with a Teflon stir bar for 24 hours. During leaching, the pH was routinely monitored and maintained at 5 using 0.5 N acetic acid and 0.25 N sodium hydroxide. After 24 hours the solution was filtered through a 0.45 µm Millipore filter and diluted to 2000 mL with deionized water. Two blanks were prepared using the same procedure.

The H_2O Only leachings were performed using the same procedure used for the RCRA leachings except that no acetic acid or sodium hydroxide was added to the solution. A blank was prepared using the same procedure.

The initial and final pH for all leachates are given in Table 6-1.

TABLE 6-1. INITIAL AND FINAL pH's FOR THE SOLID WASTE LEACHATES

Sample	Initial pH	Final pH
Dust-RCRA	5.66	5.00
Dust-H_2O Only	5.18	7.53
Ash-RCRA	8.74	5.00
Ash-H_2O Only	9.00	8.92

6.1.2 ORGANIC EXTRACTION METHODS FOR THE LEACHATES

Approximately 1750 mL of the filtered leachate was acidified to a pH of 2 with 6 N hydrochloric acid and extracted twice with 50 mL of methylene chloride for each extraction. The leachate was then extracted twice with 50 mL of diethyl ether for each extraction. The ether had been redistilled in a glass still to remove contaminates. Then, the pH of the leachate was adjusted to 12 with 6 N sodium hydroxide and the extraction procedure was repeated. The extracts were combined and the volume was recorded. A 1 mL aliquot of the combined dilute extract was retained for TCO analysis.

The extract was concentrated to 10 mL; using a 500 mL Kuderna-Danish concentrator. The concentrated extract was transferred to a hypovial which was then crimp-sealed with a Teflon-faced septum and stored in a refrigerator.

Blank extracts were prepared by extracting the blank leachates using the same procedure.

6.1.3 TOTAL ORGANIC CARBON ANALYSIS

Five milliliter aliquots of the leachates were analyzed for total organic carbon using a Dohrman DC-54 Ultra-Low Total Organic Carbon Analyzer System.

6.1.4 TOTAL CHROMATOGRAPHABLE ORGANICS ANALYSIS

TCO analyses were performed using a Tracor 560 gas chromatograph equipped with a flame ionization detector. Chromatograms were recorded with a Spectra-Physics SP-4000 data processing system. Chromatograms were compared to an n-C_7 - C_{17} + n-C_{20} boiling point standard and an n-C_8, C_{12}, C_{16} quantitative standard. The following conditions were used:

Carrier Flow:	N_2, 30 ml/minute
Injector Temperature:	275°C
Detector Temperature:	300°C
Oven Program:	50°C to 250°C at 20°C/min with an initial hold of 5 minutes and a final hold of 15 minutes
Column:	10 ft. x 2 mm ID glass column packed with 10% OV-101 on 80/100 mesh Supelcoport

Analyses were performed on the dilute and concentrated extracts of the neutral and acid leachates and blanks.

6.1.5 GRAVIMETRIC ANALYSIS

GRAV analyses were performed by transferring an 8 mL aliquot of the concentrated extract 2 mL at a time to a tared, 2.5 mL micro-beaker which had been successively rinsed with chromic acid, deionized water, methanol and methylene chloride. GRAV beakers were stored in a dessicator over silica gel and weighed with a Mettler five place analytical balance periodically at minimum 24 hour intervals until a variation of $\leq$0.1 mg was observed between weighings.

6.1.6 INFRARED ANALYSIS

IR analyses were performed on the GRAV residues with a Perkin Elmer 283 infrared spectrophotometer in absorbance mode using sodium chloride plates following dissolution of the residue in $\approx$0.5 ml of CH_2Cl_2.

6.1.7 SPARK SOURCE MASS SPECTRAL ANALYSIS

SSMS analyses were performed by Commercial Testing and Engineering Company of Golden, Colorado, using an Associated Electrical Industries Model MS7 Mattauch type double focusing mass spectrometer. The samples were prepared by mixing 20 mL of the leachate with 0.2 g of ultra-pure graphite and with indium as an internal standard. The mixture was dried at 140 - 160°C and pressed into an electrode for analysis. The spectrum was recorded on a photographic plate.

The same procedure was used for the coal except that 0.1 g. of the solid was ground to <200 mesh and mixed with 0.1 g of ultra-pure graphite.

6.2 DETAILED ORGANIC ANALYSIS

6.2.1 ACID-BASE-NEUTRAL FRACTIONATION SCHEME

Samples subjected to detailed analysis were first fractionated using an acid-base-neutral (ABN) separation scheme. All samples with a combined TCO and GRAV of >20 mg for the extract were fractionated. The cyclone dust and gasifier ash extracts were analyzed by GC/MS without fractionation. Table 6-2 lists the extracts analyzed. The fractionation scheme initially separated the extract into acidic, basic, and neutral fractions.

TABLE 6-2. ORGANIC EXTRACTS ANALYZED BY GC/MS

Stream	Sample Description
Gasifier Ash	Methylene chloride and ethyl ether extracts
Cyclone Dust	Methylene chloride extract
Coal Feeder Vent Discharge	EPA SASS Train[1]: XAD-2 resin, organic module rinses, probe rinse, condensate
Separator Vent Discharge	EPA SASS Train[1]: XAD-2 resin, organic module rinses, probe rinse, condensate
Separator Liquor	Ethyl ether extract
Separator Tar	Methylene chloride extract

[1] SASS train modified to place the XAD-2 canister downstream of the gas conditioning module.

The basic fraction did not go through additional fractionation. The acidic fraction was treated with diazomethane to selectively methylate the carboxylic acids. The fraction was then extracted with aqueous NaOH to yield 2 fractions containing methylated carboxylic acids and free phenols respectively. The phenols were extracted into ether after acidification of the aqueous solution with HCl and saturation with NaCl.

The neutral fraction was separated into 4 fractions by liquid chromatography on silica gel. The separation was performed on the basis of increasing polarity by sequential elution with pure hexane, hexane:CH_2Cl_2 (1:1), CH_2Cl_2: CH_3OH (99:1) and pure CH_3OH.

After fractionation, the 7 fractions were analyzed by GC/MS. The fractionation scheme is shown in the flow diagrams in Figures 6-1 through 6-3. A more detailed discussion of the ABN scheme is available in Reference 10.

6.2.2 GAS CHROMATOGRAPHY/MASS SPECTROMETRY: ANALYSIS AND QUANTIFICATION

Extracts and extract fractions for detailed analysis were analyzed using a Hewlett-Packard Model 5980 GC/MS system equipped with a Model 5930 data processing system.

The analytical conditions used for all extracts and fractions except the free phenol fraction were:

- Carrier: He, 25 mL/min
- Oven Program: 60°C to 300°C at 8°C/min with an initial hold of 2 min and a final hold of 8 min
- Analytical Column: 6 ft. x 2mm ID glass column packed with 1% SP-2100 on 100-120 mesh Supelcoport
- MS Span: 40-320 m/e
- MS Span Time: 3 sec

The phenols were analyzed using the same conditions except that the analytical column was packed with 60-80 mesh Tenax GC.

Quantifications of individual peaks are semi-quantitative and should be used only as an approximation of actual stream concentrations. Quantification was based on peak height measurements from the total ion plot. The peak heights were compared to the peak height of d_{10}-anthracene spiked into the final extract concentrates at 20 ng/μL as an internal

standard. Concentrations of individual compounds in the extracts were calculated using the following equation:

$$C = \frac{a \times 20}{b \times c}$$

where: C = concentration of a compound in the extract in ng/μL

a = peak height of the compound of interest in the total ion plot

b = response factor of the compound of interest relative to d_{10}-anthracene

c = peak height of d_{10}-anthracene at 20 ng/μL

If the response factor (RF) for the compound of interest was known, that RF was used. If the RF was not known, an RF of 1 was assumed except for phenols. Phenols in general display low RF's. An RF of 0.4 was used for all phenols as a conservative approximation of their actual RF's. A list of specific RF's used for compounds with known RF's relative to d_{10}-anthracene is given in the Appendix, Table A-2.

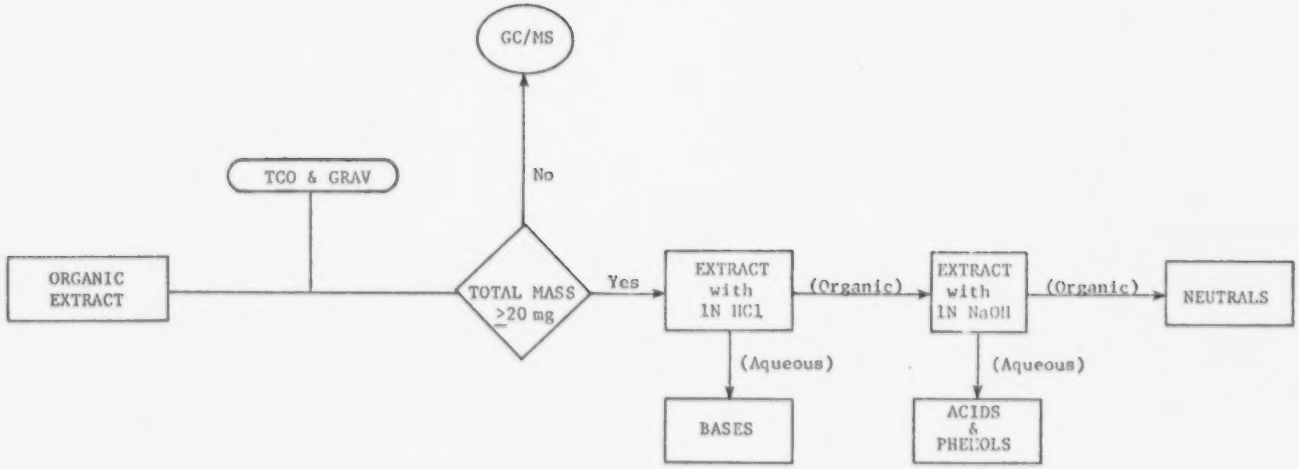


Figure 6-1. Detailed analysis flow diagram: Initial Separation

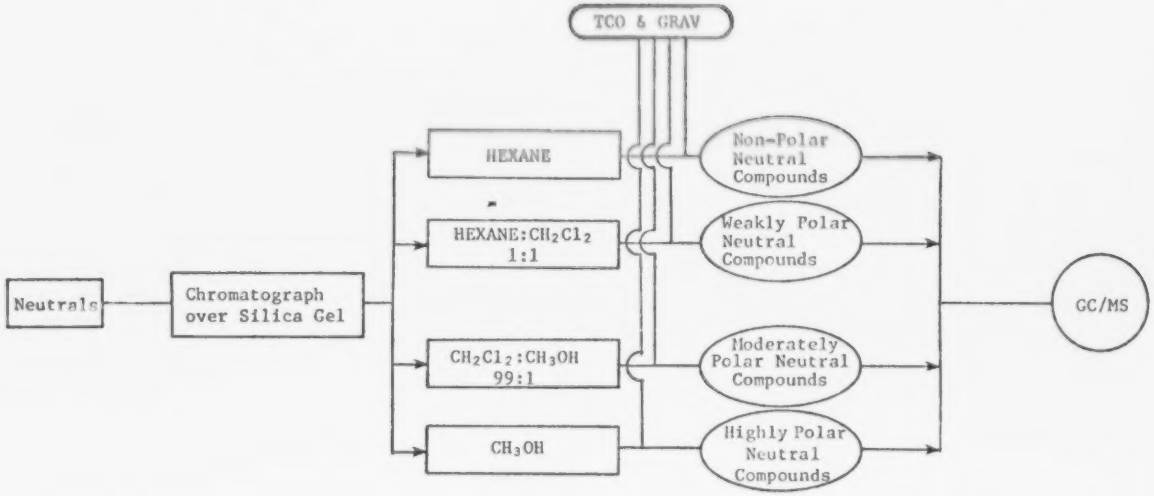


Figure 6-2. Detailed analysis flow diagram: Liquid Chromatographic Separation of the Neutral Fraction.

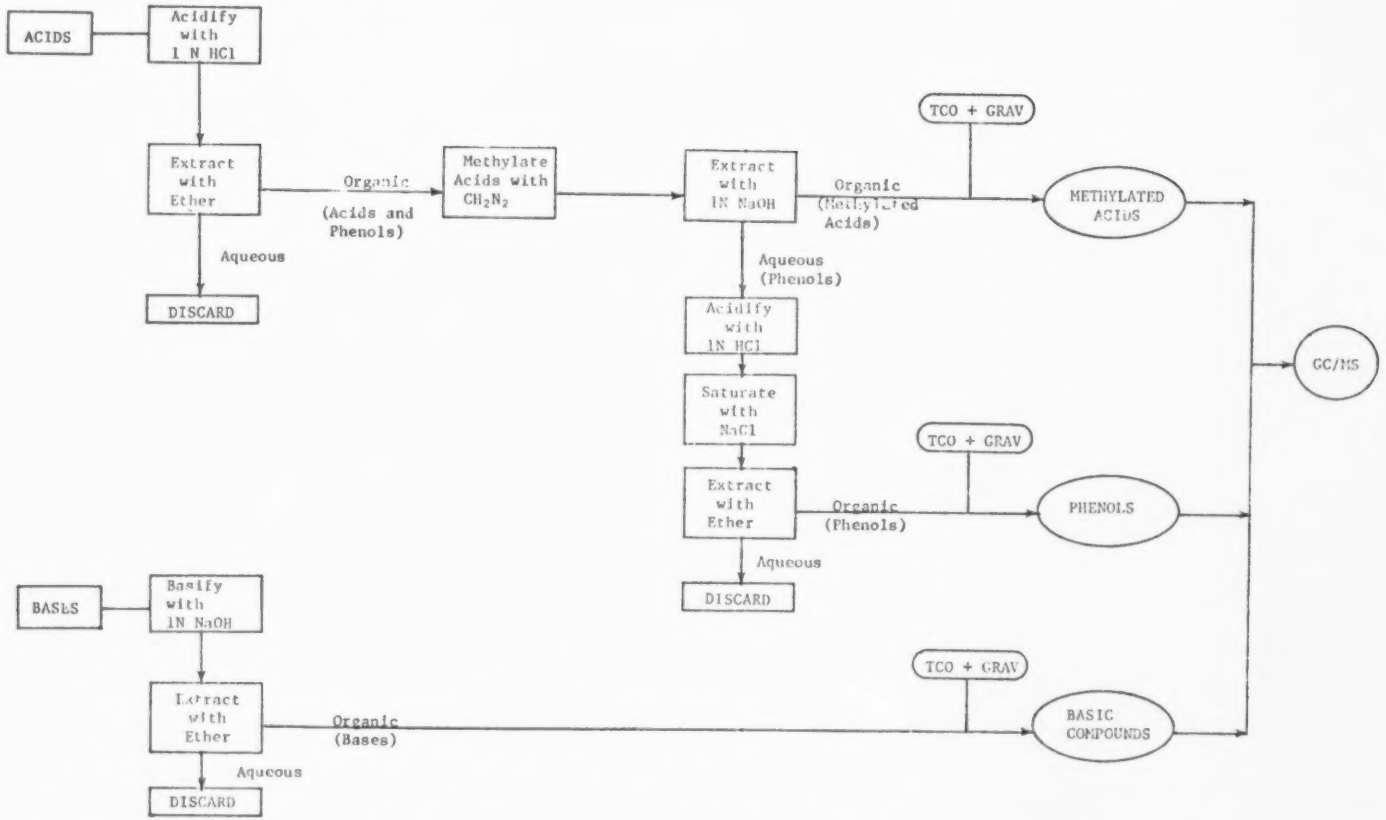


Figure 6-3. Detailed analysis flow diagram: Separation of the Acidic and Basic Fractions.

REFERENCES

1. Page, G. C. Environmental Assessment: Source Test and Evaluation Report--Chapman Low-Btu Gasification. NTIS Report PB-289 940, EPA-600/7-78-202. Radian Corp., Austin, TX, October 1978.

2. Schalit, L. M., and K. J. Wolfe. SAM/IA: A Rapid Screening Method for Environmental Assessment of Fossil Energy Process Effluents. NTIS Report PB-277 088, EPA-600/7-78-015. Acurex Corporation/Aerotherm Division, Mountain View, CA, February 1978.

3. Cleland, J. G., and G. L. Kingsbury. Multimedia Environmental Goals for Environmental Assessment: Volume I, and Volume II. MEG Charts and Background Information. NTIS Reports PB-276 919, PB-276 920, EPA-600/7-77-136a,b. Research Triangle Institute, Research Triangle Park, NC, November 1977.

4. Kingsbury, G. L., R. C. Sims, and J. B. White. Multimedia Environmental Goals for Environmental Assessment: Volume III. MEG Charts and Background Information Summaries (Categories 1-12). Report EPA-600/7-79-176a. Research Triangle Institute, Research Triangle Park, NC, August 1979.

5. Kingsbury, G. L., R. C. Sims, and J. B. White. Multimedia Environmental Goals for Environmental Assessment: Volume IV. MEG Charts and Background Information Summaries (Categories 13-26). Report EPA-600/7-79-176b. Research Triangle Institute, Research Triangle Park, NC, August 1979.

6. Environmental Protection Agency. Water Quality Criteria; Availability. Federal Register, 44(144):43660-43697, 1979.

7. Environmental Protection Agency. Hazardous Waste Management System, Identification and Listing of Hazardous Waste. Federal Register, 45(98):33084-33133, 1980.

8. Page, G. C., W. J. Rhodes, and T. K. Janes. Environmental Assessment Results and Control Technology Needs for Low-Btu Gasification Facilities. Presented at the 72nd Annual Meeting of the American Institute of Chemical Engineers, San Francisco, CA, 25-29 November 1979.

9. Environmental Protection Agency. Guidelines Establishing Test Procedures for the Analysis of Pollutants; Proposed Regulations. Federal Register, 44(233):69464-69575, 1979.

10. Oldham, R. G., and R. G. Wetherold. Assessment, Selection and Development of Procedures for Determining the Environmental Acceptability of Synthetic Fuel Plants Based on Coal, Volumes 1 thru 4. NTIS Report FE-1795-3. Radian Corp., Austin, TX, May 1977.

APPENDIX A

GC/MS Response Factors, Proposed DMEG Values
and Detailed Data Tables

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TABLE A-1. DMEG VALUES PROPOSED BY RESEARCH TRIANGLE INSTITUTE

MEG Category	Constituent	Proposed DMEG Value
50	Antimony	7.25E2(W,H)[1,2] 6.0E2(W,E)
49	Arsenic	2.0E0(W,H) 2.9E1(W,E)
15	Benzene	1.5E3(W,H) 4.6E3(W,E)
32	Beryllium	8.7E0(W,H) 8.25E2(W,E)
37	Boron	7.5E2(W,E)
	BOD	2.0E5(W,E)
82	Cadmium	5.0E0(W,E)
53	Carbon disulfide	3.0E3(A,H)
53	Carbonyl sulfide	3.8E3(A,H)
68	Chromium	8.0E-1(W,H) 5.0E1(W,E)
78	Copper	5.0E3(W,H) 3.95E0(W,E)
47	Cyanide (HCN)	5.0E3(A,H) 1.0E3(W,H) 7.0E0(W,E)
1	Ethylene	2.4E1(A,E)
8	Formic acid	1.75E4(W,E)
53	Hydrogen sulfide	2.5E4(A,E)
46	Lead	2.5E2(W,H) 2.22E4(W,E)
83	Mercury	1.0E0(W,H) 3.2E-1(W,E)

(Continued)

TABLE A-1 (Continued)

DMEG VALUES PROPOSED BY RESEARCH TRIANGLE INSTITUTE

MEG Category	Constituent	Proposed DMEG Value
76	Nickel	2.5E2(W,H) 1.1E3(W,E)
	Oil and Grease	5.0E2(W,E)
18	Phenol	1.7E4(W,H) 3.0E3(W,E)
54	Selenium	2.2E1(W,E)
79	Silver	5.0E1(W,H) 4.5E-2(W,E)
28	Sodium	1.0E5(W,H)
53	Sulfide	2.5E2(W,H) 1.0E1(W,E)
53	Thiocyanate	8.70E3(W,E)
45	Tin	3.0E4(W,H)
	TDS	1.3E6(W,H) 2.5E6(W,E)
15	Toluene	8.7E4(W,H) 5.0E2(W,E)
81	Zinc	8.44E4(W,E)

[1] $aEb = a \times 10^b$

[2] Letters in parentheses indicate applicability of DMEG value; W,H = Water, health; W,E = Water ecology; A,H = Air, health; A,E = Air, ecology.

TABLE A-2. RESPONSE FACTORS RELATIVE TO d_{10}-ANTHRACENE USED IN GC/MS DATA CALCULATIONS

Compound	RF
Naphthalene and alkyl derivatives	0.637
Acenaphthylene and alkyl derivatives	0.783
Acenaphthene and alkyl derivatives	0.483
Fluoranthene and alkyl derivatives	0.837
Benz(a)anthracene	1.26
Benzoperylene	1.04
Phenols	0.4
All others	1.0

A KEY TO THE USE OF TABLES A-3 THROUGH A-8:
DETAILED ORGANIC ANALYSIS RESULTS

1. $aEb = a \times 10^{b}$

2. NA = DMEG value not available.

3. Estimated dc = estimated stream concentration

4. DS = Discharge severity = $\frac{dc}{DMEG}$

5. DMEG = Discharge multimedia environmental goal.

6. a/b indicates that the compound may be a and/or b. "Worst case" DMEG values are used for calculating DS values.

7. (≤a isomers) indicates that the compound is not distinguished from a isomers of the same molecular weight. "Worst case" DS values are calculated assuming the total mass of the isomeric group to be the listed compound.

8. Many amines are not distinguished from their heterocyclic isomers. DS values are calculated for the amine in category 10 and again for the heterocyclic isomer in category 23.

9. DMEG values for phenols are proposed values from Table A-1.

TABLE A-3. DETAILED ORGANIC ANALYSIS: GASIFIER ASH [1]

MEG NO	CATEGORY NAME	COMPOUND	ESTIMATED dc (µg/g)	DMEG VALUE HEALTH	DMEG VALUE ECOLOGY	DS HEALTH	DS ECOLOGY
1	Aliphatics	>C_6 Alkanes	3 E-1	1.1 E6	2.0 E3	3 E-7	2 E-4
8	Carboxylic Acids	Phthalates	3	1.5 E4	8.0 E-1	2 E-4	4
15	Benzenes	C_2-Alkylbenzene	1 E-1	1.3 E6	2.0 E2	8 E-8	5 E-4
16	Fused Aromatics	Naphthalene	2 E-1	1.5 E5	2.0 E1	1 E-6	1 E-2
		Methylnaphthalene	4 E-1	6.76 E5	NA	6 E-7	--

[1] See Page A-5 for explanation of table.

TABLE A-4. DETAILED ORGANIC ANALYSIS: CYCLONE DUST [1]

MEG NO	CATEGORY NAME	COMPOUND	ESTIMATED dc (µg/g)	DMEG VALUE HEALTH	DMEG VALUE ECOLOGY	DS HEALTH	DS ECOLOGY
8	Carboxylic Acids	Phthalates	8 E-2	1.5 E4	8.0 E-1	5 E-6	1 E-1
		Adipates	4 E-2	2.16 E5	NA	2 E-7	--
21	Fused Polycyclics	Naphthalene	5 E-2	1.5 E5	2 E1	3 E-7	3 E-3

[1] See Page A-5 for explanation of table.

TABLE A-5. DETAILED ORGANIC ANALYSIS: COAL FEEDER VENT DISCHARGE[1]

MEG CATEGORY NO.	NAME	COMPOUND	ESTIMATED dc ($\mu g/m^3$)	DMEG VALUE HEALTH	DS HEALTH
1	Aliphatics	>C_6 Alkanes	2 E2	3.5 E5	8 E-4
		≥C_{13} Alkanes	3 E3	NA	--
5	Alcohols	>C_6 Aliphatic	2 E2	1.1 E6	2 E-4
		≥C_{13} Aliphatic	2 E1	NA	--
8	Carboxylic Acids	Phthalic Acid	1 E2	2.07 E5	5 E-4
		Phthalates	7 E2	5.0 E3	1 E-1
10	Amines	Pyrrolidine	6 E1	NA	--
		Aminonaphthalene/ Methylquinoline	1 E2	5.64 E2	2 E-1
		Methylamino-naphthalene/C_2-Alkylquinoline	2 E2	NA	--
15	Benzenes	C_2-Alkylbenzene	2 E3	4.35 E5	5 E-3
		C_3-Alkylbenzene	7 E2	1.2 E5	6 E-3
		Styrene	2 E2	1.3 E5	2 E-3
		Indan/ C_3-Alkenylbenzene	2 E3	4.2 E5	5 E-3
		Tetrahydronaphtha-lene/Methylindan	1 E3	NA	--
			2 E2		9 E-4
		Dihydronaphthalene/ Methylindene	1 E3	1.27 E5	8 E-3
18	Phenols	Phenol	3 E2	1.9 E4	2 E-2
		Cresol	8 E2	1.0 E4	8 E-2
		C_2-Alkylphenol	8 E2	1.0 E4	8 E-2
		C_3-Alkylphenol	1 E2	2.4 E4	4 E-3
		C_4-Alkylphenol	9	5.9 E4	2 E-4
		Indenol	1 E2	NA	--
		Indanol	1 E2	1.5 E5	7 E-4

(Continued)

TABLE A-5 (Continued). DETAILED ORGANIC ANALYSIS: COAL FEEDER VENT DISCHARGE[1]

MEG CATEGORY NO.	MEG CATEGORY NAME	COMPOUND	ESTIMATED dc ($\mu g/m^3$)	DMEG VALUE HEALTH	DS HEALTH
18	Phenols (Continued)	Naphthol	2 E2	1.09 E5	2 E-3
		Methylnaphthol	3 E2	NA	--
		C_2-Alkylnaphthol	2 E1	NA	--
		Hydroxyace-naphthylene	5 E1	NA	--
		Methylhydroxyace-naphthylene	3 E1	NA	--
		Phenylphenol/ Acenaphthol	5 E1	2.25 E4	2 E-3
		Methylphenylphenol/ Methylacenaphthol	7 E1	NA	--
		C_2-Alkylphenylphenol/ C_2-Alkylacenaphthol	1 E2	NA	--
		C_3-Alkylphenylphenol/ C_3-Alkylacenaphthol	6 E1	NA	--
		Hydroxyphenathrene/ Hydroxyanthracene	3 E1	NA	--
21	Fused Polycyclics	Naphthalene	1 E4	5.0 E4	2 E-1
		Methylnaphthalene	1 E4	2.25 E5	4 E-2
		C_2-Alkylnaphthalene	2 E3	2.25 E5	9 E-3
		Methylacenaphthene/ Dibenzofuran/Methyl-biphenyl	8 E2	NA	--
		C_2-Alkylacenaphthene/ Methyldibenzofuran/ C_2-Alkylbiphenyl	4 E2	NA	--
		Acenaphthylene	5 E3	NA	--
		Methylacenaphthy-lene/Fluorene	2 E4	NA	--
		C_2-Alkylacenaphthy-lene/Methylfluorene	1 E3	NA	--
		Phenanthrene/Anthra-cene	3 E3	1.6 E3	2

(Continued)

TABLE A-5 (Continued). DETAILED ORGANIC ANALYSIS: COAL FEEDER VENT DISCHARGE[1]

MEG CATEGORY NO.	NAME	COMPOUND	ESTIMATED dc ($\mu g/m^3$)	DMEG VALUE HEALTH	DS HEALTH
21	Fused Polycyclics (Continued)	Methylphenanthrene/ Methylanthracene	2 E3	NA	--
		Benz(a)anthracene ($\leq$5 isomers)	1 E3	4.5 E1	2 E1
		Benzo(a)pyrene ($\leq$6 isomers)	8 E2	2.0 E-2	4 E4
		Benzoperylene	3 E2	NA	--
22	Fused Non-Alternants	Indene	6 E3	4.4 E4	1 E-1
		Fluoranthene/Pyrene	2 E3	9.0 E4	2 E-2
23	Nitrogen Heterocycles	Quinoline	5 E1	1.6 E4	3 E-3
		Methylquinoline/ Aminonaphthalene	1 E2	5.5 E4	2 E-3
		C_2-Alkylquinoline/ Methylaminonaphthalene	2 E2	5.54 E4	4 E-3
		Carbazole	5 E1	2.3 E4	2 E-3
		Acridine/Benzo-quinoline/Phenan-thridine	2 E2	9.0 E4	2 E-3
		Methylacridine/Methyl-benzoquinoline/Methyl-phenanthridine	1 E2	NA	--
		Benzoacridine/Dibenzo-quinoline/Benzophenan-thridine	8 E1	1.1 E4	7 E-3
		Methylbenzoacridine/ Methyldibenzoquinoline/ Methylbenzophenanthridine	6 E1	NA	--

[1] See Page A-3 for explanation of table.

TABLE A-6. DETAILED ORGANIC ANALYSIS: SEPARATOR VENT DISCHARGE[1]

MEG CATEGORY NO.	MEG CATEGORY NAME	COMPOUND	ESTIMATED dc ($\mu g/m^3$)	DMEG VALUE HEALTH	DS HEALTH
1	Aliphatics	>C_6 Alkanes	2 E3	1.1 E6	2 E-3
3	Ethers	Methylanisole	3 E3	NA	--
5	Alcohols	>C_6 Aliphatic	2 E1	1.6 E5	1 E-4
7	Aldehydes/ Ketones	Methylacetophenone	2 E1	NA	--
8	Carboxylic Acids	Phthalates	2 E3	5.0 E3	4 E-1
		Adipates	9 E3	1.9 E4	5 E-1
9	Nitriles	Benzonitrile	1 E2	3.2 E4	3 E-3
		Cyanotoluene	1 E1	NA	--
10	Amines	Aniline	1 E2	1.9 E4	5 E-3
		Aminotoluene	4 E2	1.1 E2	4
		Aminonaphthalene/ Methylquinoline	3 E3	1.65 E2	2
		Methylaminonaphthalene/C_2-Alkylquinoline	2 E2	NA	--
		C_2-Alkylaminonaphthalene/C_3- Alkylquinoline	6 E1	NA	--
15	Benzenes	C_2-Alkylbenzene	3 E2	4.4 E5	7 E-4
		C_3-Alkylbenzene	7 E2	2.2 E5	3 E-3
		Phenylacetylene	2 E2		
		Indan/C_3-Alkenylbenzene	2 E3	2.25 E5	9 E-3
		Dihydronaphthalene/ Methylindene	5 E3	1.27 E5	4 E-2
		Methyldihydronaphthalene/C_2-Alkylindene	3 E3	NA	--

(Continued)

TABLE A-6 (Continued). DETAILED ORGANIC ANALYSIS: SEPARATOR VENT DISCHARGE[1]

MEG CATEGORY NO.	MEG CATEGORY NAME	COMPOUND	ESTIMATED dc ($\mu g/m^3$)	DMEG VALUE HEALTH	DS HEALTH
15	Benzenes (Continued)	C_2-Alkyldihydronaphthalene/C_3-alkylindene	1 E3	NA	--
		Tetrahydronaphthalene/Methylindan	7 E2	1.3 E5	5 E-3
		Methyltetrahydronaphthalene/C_2-Alkylindan	3 E3	NA	--
		C_2-Alkyltetrahydronaphthalene/C_3-Alkylindan	4 E3	NA	--
		Biphenyl/Acenaphthene	9 E3	1.0 E3	9
		Methylbiphenyl/Methylacenaphthene	4 E3	NA	--
		C_2-Alkylbiphenyl/C_2-Alkylacenaphthene	6 E2	NA	--
		C_3-Alkylbiphenyl/C_3-Alkylacenaphthene	8 E2	NA	--
18	Phenols	Phenol	3 E5	1.9 E4	2 E1
		Cresol	5 E5	1.0 E4	5 E1
		C_2-Alkylphenol	7 E5	1.0 E4	7 E-1
		C_3-Alkylphenol	2 E4	2.4 E4	8 E-1
		C_4-Alkylphenol	8 E2	5.9 E4	1 E-2
21	Fused Polycyclics	Naphthalene	5 E3	5.0 E4	1 E-1
		Methylnaphthalene	2 E4	2.3 E5	9 E-2
		C_2-Alkylnaphthalene	7 E3	2.3 E5	3 E-2
		Acenaphthylene	3 E3	NA	--
		Methylacenaphthylene/Fluorene	1 E3	NA	--
		C_2-Alkylacenaphthylene/Methylfluorene	6 E2	NA	--

(Continued)

TABLE A-6 (Continued). DETAILED ORGANIC ANALYSIS: SEPARATOR VENT DISCHARGE[1]

MEG CATEGORY NO.	MEG CATEGORY NAME	COMPOUND	ESTIMATED dc ($\mu g/m^3$)	DMEG VALUE HEALTH	DS HEALTH
21	Fused Polycyclics (Continued)	Phenanthrene/ Anthracene	1 E3	1.6 E3	6 E-1
		Methylphenanthrene/ Methylanthracene	1 E2	NA	--
22	Fused Non-Alternants	Indene	4 E3	4.5 E4	3 E-2
23	Nitrogen Heterocycles	Pyridine	2 E2	1.5 E4	1 E-2
		Picoline	6 E2	6.9 E4	9 E-3
		C_2-Alkylpyridine	2 E3	1.8 E4	1 E-1
		C_3-Alkylpyridine	1 E3	1.8 E4	6 E-2
		C_4-Alkylpyridine	2 E2	1.8 E4	1 E-2
		Quinoline	2 E2	1.6 E4	1 E-2
		Methylquinoline/ Aminonaphthalene	3 E3	5.5 E4	5 E-2
		C_2-Alkylquinoline/ Methylaminonaphthalene	2 E2	5.5 E4	4 E-3
		C_3-Alkylquinoline/ C_3-Alkylaminonaphthalene	6 E1	NA	--
25	Sulfur Heterocycles	Benzothiophene	2 E2	2.3 E4	9 E-3

[1] See Page A-5 for explanation of table.

TABLE A-7. DETAILED ORGANIC ANALYSIS: SEPARATOR LIQUOR [1]

MEG CATEGORY NO.	MEG CATEGORY NAME	COMPOUND	ESTIMATED dc (µg/l)	DMEG VALUE HEALTH	DMEG VALUE ECOLOGY	DS HEALTH	DS ECOLOGY
1	Aliphatics	$\geq C_6$ Alkanes	2 E2	5.3 E6	1.0 E5	4 E-4	2 E-2
5	Alcohols	$>C_6$ Aliphatic	2 E2	2.4 E6	NA	8 E-5	--
		$>C_{15}$ Aliphatic	1 E4	NA	NA	--	--
8	Carboxylic Acids	Phthalic Acid	1 E4	3.1 E6	NA	2 E-3	--
		Phthalates	7 E2	7.5 E4	1.5	1 E-2	5 E2
		Adipates	6 E2	1.08 E6	NA	6 E-4	--
10	Amines	Aniline/Picoline	3 E2	2.9 E5	1.0 E3	2 E-2	3 E-1
		Aminotoluene/C_2-Alkylpyridine	4 E2	1.65 E3	NA	2 E-1	--
		C_2-Alkylaniline/ C_3-Alkylpyridine	1 E2	3.75 E3	NA	3 E-2	--
		Methylpyrrolene	6 E1	NA	NA	--	--
		Methylaminoindane	8 E1	NA	NA	--	--
		Methylaminoindene	2 E2	NA	NA	--	--
		Aminonaphthalene/ Methylquinoline	9 E1	2.5 E3	1.0 E2	4 E-2	9 E-1
15	Benzenes	Dihydronaphthalene/ Methylindene	9 E1	1.91 E6	NA	5 E-5	--
18	Phenols	Phenol	6 E5	1.7 E4	3.0 E3	4 E1	2E2
		Cresol	1 E6	1.7 E4	3.0 E3	6 E1	3E2
		C_2-Alkylphenol	3 E5	1.7 E4	3.0 E3	2 E1	1E2
		C_3-Alkylphenol	6 E3	1.7 E4	3.0 E3	4 E-1	2
		Dihydroxybenzene	1 E4	1.7 E4	3.0 E3	6 E-1	3
		Methyldihydroxy-benzene	2 E3	NA	NA	--	--
		Indenol	1 E3	NA	NA	--	--
		Naphthol	1 E3	1.7 E4	3.0 E3	5 E-2	3 E-1

(Continued)

TABLE A-7 (Continued). DETAILED ORGANIC ANALYSIS: SEPARATOR LIQUOR [1]

MEG CATEGORY NO.	MEG CATEGORY NAME	COMPOUND	ESTIMATED dc (µg/l)	DMEG VALUE HEALTH	DMEG VALUE ECOLOGY	DS HEALTH	DS ECOLOGY
21	Fused Polycyclics	Naphthalene	8 E2	7.5 E5	1.0 E2	9 E-2	8
		Methylnaphthalene	4 E2	3.38 E6	NA	1 E-4	--
		C_2-Alkylnaphthalene	1 E2	3.38 E6	NA	3 E-5	--
		Acenaphthylene	4 E2	NA	NA	--	--
		Benzoperylene	9 E2				
22	Fused Non-Alternants	Indene	8 E2	6.8 E5	NA	3 E-4	--
23	Nitrogen Heterocycles	Picoline/Aniline	3 E2	5.3 E5	NA	6 E-4	--
		C_2-Alkylpyridine/ Aminotoluene	4 E2	2.7 E5	1 E4	2 E-3	4 E-2
		C_3-Alkylpyridine/ C_2-Alkylaniline	1 E2	2.7 E5	1 E4	4 E-4	1 E-2
		C_3-Alkylpyrrole	1 E2	NA	NA	--	--
		Indole	2 E3	1.7 E5	NA	1 E-2	--
		Methylindole	4 E2	6.8 E5	NA	6 E-4	--
		Quinoline	2 E2	2.4 E5	NA	8 E-4	--
		Methylquinoline/ Aminonaphthalene	9 E1	8.3 E5	NA	1 E-4	--

[1] See Page A-5 for explanation of table.

TABLE A-8. DETAILED ORGANIC ANALYSIS: SEPARATOR TAR [1]

MEG CATEGORY			ESTIMATED	DMEG VALUE	DS
No.	Name	Compound	dc (µg/L)	Health	Health
1	Aliphatics	>C_6 Alkanes	2E4	5.3E6	4E-3
		≥C_{13} Alkanes	3E5	NA	--
5	Alcohols	>C_6 Aliphatic	6E5	2.4E6	3E-1
8	Carboxylic Acids	Phthalic Acid	3E5	3.1E6	1E-1
		Phthalates	9E6	7.5E4	1E2
		Adipates	8E6	1.08E6	7
		>C_9 Aliphatic Esters	5E4	NA	--
10	Amines	C_2-Alkylaniline/ C_3-Alkylpyridine	2E3	3.75E5	5E-3
		C_3-Alkylaniline/ C_4-Alkylpyridine	2E4	NA	--
		Aminotetralin/Methyl-aminoindane	9E5	NA	--
		Aminonaphthalene/ Methylquinoline	1E5	2.5E3	4E1
		Methylaminonaphthalene/ C_2-Alkylquinoline	1E5	NA	--
		C_2-Alkylaminonaphthalene/ C_3-Alkylquinoline	5E4	NA	--
		Aminoacenaphthylene/ Carbazole	2E4	NA	--
		Methylaminoacenaphthylene/ Aminofluorene/Methylcarbazole	3E4	NA	--
		Aminopyrene/Aminofluoranthene	3E4	NA	--
		Benzoaminofluorene	2E4	NA	--
		Methylbenzoaminofluorene	8E3	NA	--

(Continued)

TABLE A-8 (Continued). DETAILED ORGANIC ANALYSIS: SEPARATOR TAR [1]

MEG CATEGORY			ESTIMATED	DMEG VALUE	DS
No.	Name	Compound	dc (µg/L)	Health	Health
15	Benzenes	Dihydronaphthalene/ Methylindene	1E5	1.91E6	5E-2
		Methyldihydronaphthalene/ C_2-Alkylindene	1E5	NA	--
		Biphenyl/Acenaphthene	9E5	1.5E4	6E1
		Methylbiphenyl/ Methylacenaphthene	2E5	NA	--
		C_2-Alkylbiphenyl/ C_2-Alkylacenaphthene	6E5	NA	--
		C_3-Alkylbiphenyl/ C_3-Alkylacnaphthene	5E5	NA	--
18	Phenols	Phenol	6E5	1.7E4	4E1
		Cresol	3E6	1.7E4	2E2
		C_2-Alkylphenol	2E6	1.7E4	1E2
		C_3-Alkylphenol	2E5	1.7E4	1E1
		Indanol	1E5	1.7E4	6
		Indenol	1E5	NA	--
		Naphthol	6E5	1.7E4	4E1
		Methylnaphthol	6E5	NA	--
		C_2-Alkylnaphthol	8E4	NA	--
		Phenylphenol/Acenaphthol	9E4	1.7E4	5
		Methylphenylphenol/ Methylacenaphthol	3E4	NA	--
		C_2-Alkylphenylphenol/ C_2-Alkylacenaphthol	3E5	NA	--
		C_3-Alkylphenylphenol/ C_3-Alkylacenaphthol	6E4	NA	--
		Methylhydroxyacenaphthylene/ Fluorenol	2E4	NA	--
		Hydroxyanthracene/ Hydroxyphenanthrene	5E4	NA	--

(Continued)

TABLE A-8 (Continued). DETAILED ORGANIC ANALYSIS: SEPARATOR TAR [1]

MEG CATEGORY			ESTIMATED	DMEG VALUE	DS
No.	Name	Compound	dc (µg/L)	Health	Health
18	Phenols (Continued)	C_5-Alkylhydroxyanthracene/ C_5-Alkylhydroxyphenanthrene	9E4	NA	--
		C_3-Alkylhydroxypyrene/ C_3-Alkylhydroxyfluoranthene	2E5	NA	--
		Hydroxybenzofluorene	3E5	NA	--
21	Fused Polycyclics	Naphthalene	1E6	7.5E5	1
		Methylnaphthalene	2E6	3.38E6	6E-1
		C_2-Alkylnaphthalene	2E6	3.38E6	6E-1
		Acenaphthylene	3E6	NA	--
		Methylacenaphthylene/ Fluorene	3E6	NA	--
		C_2-Alkylacenaphthylene/ Methylfluorene	2E6	NA	--
		Phenanthrene/Anthracene	3E6	2.4E4	1E2
		Methylphenanthrene/ Methylanthracene	1E6	NA	--
		C_2-Alkylphenanthrene/ C_2-Alkylanthracene	3E5	NA	--
		Benz(a)anthracene (≤5 isomers)	9E5	6.7E2	1E3
		Methylbenzophenanthrene (≤5 isomers)	9E5	3.36E3	3E2
		Benzo(a)pyrene (≤6 isomers)	8E5	3E-1	3E6
		Benzoperylene	2E5	NA	--
22	Fused Non-Alternants	Indene	5E5	6.75E5	7E-2
		Fluoranthene/Pyrene	2E6	1.4E6	1
		Methylpyrene/ Benzofluorene	3E6	NA	--

(Continued)

TABLE A-8 (Continued). DETAILED ORGANIC ANALYSIS: SEPARATOR TAR [1]

MEG CATEGORY			ESTIMATED	DMEG VALUE	DS
No.	Name	Compound	dc (µg/L)	Health	Health
23	Nitrogen Heterocycles	C_3-Alkylpyridine/ C_2-Alkylaniline	2E3	1.0E6	2E-3
		C_4-Alkylpyridine/ C_3-Alkylaniline	2E4	2.7E5	7E-2
		Quinoline	6E6	2.4E5	3E1
		Methylquinoline/ Aminonaphthalene	1E5	8.3E5	1E-1
		C_2-Alkylquinoline/ Methylaminonaphthalene	1E5	8.3E5	1E-1
		C_3-Alkylquinoline/ C_2-Alkylaminonaphthalene	5E4	NA	--
		Carbazole/ Aminoacenaphthylene	2E4	3.5E5	6E-2
		Methylcarbazole/Aminofluorene/ Methylaminoacenaphthylene	3E4	3.4E5	8E-2
		Acridine/Benzoquinoline/ Phenanthridine	3E4	1.4E6	2E-2
		Methylacridine/Methlybenzo-quinoline/Methylphenanthridine	9E4	NA	--
		C_2-Alkylacridine/ C_2-Alkylbenzoquinoline	3E4	NA	--
		C_3-Alkylacridine/ C_3-Alkylbenzoquinoline	8E3	NA	--
24	Oxygen Heterocycles	Dibenzofuran	6E5	NA	--

[1] See Page A-5 for explanation of table.

TABLE A-9. SUMMARY OF ORGANIC ANALYSIS DATA
FOR THE GASIFIER ASH LEACHATES

TOC:	RCRA[1]	= 0 mg/L
	H_2O[2]	= 0.3 mg/L
TCO:	RCRA	= 0 mg/L
	H_2O	= 0 mg/L
GRAV:	RCRA	= 0 mg/L
	H_2O	= 0 mg/L
IR:	All peaks attributable to blank	

[1]RCRA = Leachate obtained using RCRA procedure.

[2]H_2O = Leachate obtained using deionized water only.

TABLE A-10. SUMMARY OF ORGANIC ANALYSIS DATA
FOR THE CYCLONE DUST LEACHATES

TOC:	RCRA[1]	= 0 mg/L
	H_2O[2]	= 0.4 mg/L
TCO:	RCRA	= 0 mg/L
	H_2O	= 0 mg/L
GRAV:	RCRA	= 0 mg/L
	H_2O	= 0 mg/L
IR:	All peaks attributable to blank.	

[1]RCRA = Leachate obtained using RCRA procedures.

[2]H_2O = Leachate obtained using deionized water only.

A KEY TO THE USE OF TABLES A-11 THROUGH A-13: SPARK SOURCE MASS SPECTRAL DATA

1. Values for leachates represent net values after blank values have been subtracted from sample values.

2. RCRA leachate = leachate produced by RCRA procedures.

3. H_2O Only leachate = leachate produced by RCRA procedures but with no buffer added.

4. $\leq$BC = less than or equal to the concentration of the element in the blank.

5. ND = not detected. Detection limits = 2 µg/L for liquids and 0.1 µg/g for solids.

6. * = heterogenous. Actual concentrations are $\leq$ starred concentrations.

7. STD = internal standard.

TABLE A-11. SPARK SOURCE MASS SPECTRAL DATA FOR THE GASIFIER ASH LEACHATES [1]

Element	RCRA (µg/L)	H_2O Only (µg/L)	Element	RCRA (µg/L)	H_2O Only (µg/L)
Aluminum	<BC	<BC	Neodymium	ND	ND
Antimony	ND	ND	Nickel	<BC	<BC
Arsenic	10	3	Niobium	ND	ND
Barium	2000	<BC	Osmium	ND	ND
Beryllium	ND	ND	Palladium	ND	ND
Bismuth	ND	ND	Phosphorous	<BC	100
Boron	20	3	Platinum	ND	ND
Bromine	<BC	20	Potassium	5000	900
Cadmium	ND	ND	Praseodymium	ND	ND
Calcium	>6000	>6000	Rhenium	ND	ND
Cerium	<1	<BC	Rhodium	ND	ND
Cesium	ND	ND	Rubidium	3	3
Chlorine	200	400	Ruthenium	ND	ND
Chromium	<3	<BC	Samarium	ND	ND
Cobalt	<BC	<BC	Scandium	<1	<BC
Copper	30	<BC	Selenium	2	<BC
Dysprosium	ND	ND	Silicon	7000	100
Erbium	ND	ND	Silver	ND	ND
Europium	ND	ND	Sodium	2000	200
Fluorine	≈3000	<BC	Strontium	3000	100
Gadolinium	ND	ND	Sulfur	>9700	<BC
Gallium	ND	ND	Tantalum	ND	ND
Germanium	4	ND	Tellurium	ND	ND
Gold	2	ND	Terbium	ND	ND
Hafnium	ND	ND	Thallium	ND	ND
Holmium	ND	ND	Thorium	ND	<8
Iodine	ND	ND	Thulium	ND	ND
Indium	STD	STD	Tin	ND	ND
Iridium	ND	ND	Titanium	100	<BC
Iron	5000	<BC	Tungsten	ND	ND
Lanthanum	ND	ND	Uranium	ND	<7
Lead	10	<BC	Vanadium	ND	ND
Lithium	ND	ND	Ytterbium	ND	ND
Lutecium	ND	ND	Yttrium	ND	ND
Magnesium	>9960	1000	Zinc	<BC	1000
Manganese	100	1	Zirconium	ND	ND
Molybdenum	< BC	<BC			

[1] See Page A-22 for explanation of table.

TABLE A-12. SPARK SOURCE MASS SPECTRAL DATA FOR THE CYCLONE DUST LEACHATES [1]

Element	RCRA (μg/L)	H_2O Only (μg/L)	Element	RCRA (μg/L)	H_2O Only (μg/L)
Aluminum	≤BC	400*	Neodymium	ND	ND
Antimony	ND	ND	Nickel	30	≤BC
Arsenic	20*	20	Niobium	ND	ND
Barium	300	ND	Osmium	ND	ND
Beryllium	ND	ND	Palladium	ND	ND
Bismuth	ND	ND	Phosphorous	≤BC	500
Boron	2	≤BC	Platinum	ND	ND
Bromine	≤BC	40	Potassium	800	7000
Cadmium	ND	ND	Praseodymium	ND	ND
Calcium	≤6000	≤BC	Rhenium	ND	ND
Cerium	ND	ND	Rhodium	ND	ND
Cesium	ND	ND	Rubidium	ND	≤BC
Chlorine	300	2000	Ruthenium	ND	ND
Chromium	≤8	≤BC	Samarium	ND	ND
Cobalt	3	≤BC	Scandium	≤BC	ND
Copper	20	≤BC	Selenium	ND	ND
Dysprosium	ND	ND	Silicon	≤BC	>9800*
Erbium	ND	ND	Silver	≤2	ND
Europium	ND	ND	Sodium	500	>4000
Fluorine	≤BC	≤BC	Strontium	100	≤BC
Gadolinium	ND	ND	Sulfur	400	200
Gallium	30*	ND	Tantalum	ND	ND
Germanium	ND	ND	Tellurium	ND	ND
Gold	30	ND	Terbium	ND	ND
Hafnium	ND	ND	Thallium	ND	ND
Holmium	ND	ND	Thorium	ND	≤10
Iodine	ND	ND	Thulium	ND	ND
Indium	STD	STD	Tin	ND	ND
Iridium	ND	ND	Titanium	≤BC	≤BC
Iron	≤BC	ND	Tungsten	ND	ND
Lanthanum	ND	ND	Uranium	ND	≤10
Lead	≤BC	≤BC	Vanadium	ND	ND
Lithium	9	ND	Ytterbium	ND	ND
Lutecium	ND	ND	Yttrium	ND	ND
Magnesium	400	300	Zinc	≤BC	≤BC
Manganese	90	3	Zirconium	ND	ND
Molybdenum	200*	≤BC			

[1] See Page A-22 for explanation of table.

TABLE A-13. SPARK SOURCE MASS SPECTRAL DATA FOR THE FEED COAL [1]

Element	Concentration µg/g	Element	Concentration µg/g
Aluminum	>100	Neodymium	25
Antimony	ND	Nickel	10
Arsenic	2	Niobium	12
Barium	110	Osmium	ND
Beryllium	≤0.1	Palladium	ND
Bismuth	ND	Phosphorous	170
Boron	1	Platinum	ND
Bromine	0.4	Potassium	>1000
Cadmium	0.7	Praseodymium	5
Calcium	>1000	Rhenium	ND
Cerium	ND	Rhodium	ND
Cesium	59	Rubidium	4
Chlorine	14	Ruthenium	ND
Chromium	26	Samarium	5
Cobalt	2	Scandium	3
Copper	14*	Selenium	5
Dysprosium	2	Silicon	>1000
Erbium	0.9	Silver	≤0.8*
Europium	0.6	Sodium	86
Fluorine	≃79	Strontium	160
Gadolinium	1	Sulfur	>630
Gallium	8	Tantalum	ND
Germanium	0.6	Tellurium	ND
Gold	≤0.1*	Terbium	0.2
Hafnium	ND	Thallium	ND
Holmium	1	Thorium	10
Iodine	2	Thulium	ND
Indium	STD	Tin	0.9
Iridium	ND	Titanium	≤1000
Iron	>1000	Tungsten	ND
Lanthanum	42	Uranium	4
Lead	5	Vanadium	19
Lithium	3	Ytterbium	ND
Lutecium	ND	Yttrium	33
Magnesium	120	Zinc	7
Manganese	13	Zirconium	65
Molybdenum	3		

[1] See Page A-22 for explanation of table.

APPENDIX B

GLOSSARY OF SOURCE ASSESSMENT MODEL/1A TERMINOLOGY

Discharge Severity (DS), a simple index of the potential harmful health or ecological effects of a substance in a discharge stream. The DS does not take synergistic effects or dispersal modes into consideration the DS is calculated using:

$$DS = \frac{dc}{DMEG}$$

DS replaces potential degree of hazard (PDOH) in SAM/1A terminology.

Weighted Discharge Severity (WDS), a simple index which reflects discharge severity and total mass emitted. WDS is calculated by:

$$WDS = DS \times mr$$

where mr is the total quantity of the stream discharge per unit of time.

WDS replaces potential toxic unit discharge rate (PTDUR) in SAM/1A terminology.

Total Discharge Severity (TDS), the sum of the DS values for a stream.

Total Weighted Discharge Severity (TWDS), the sum of the WDS values for a stream.

Discharge Multimedia Environmental Goal (DMEG), a concentration of a substance estimated not to cause adverse effects in a health or ecological receptor exposed once or intermittently for short periods, or represents control limits achievable through technology. The DMEG's are target values for components in a discharge stream.

Discharge Concentration (dc), the concentration of a substance in a discharge stream expressed in $\mu g/g$, $\mu g/L$ or $\mu g/m^3$.